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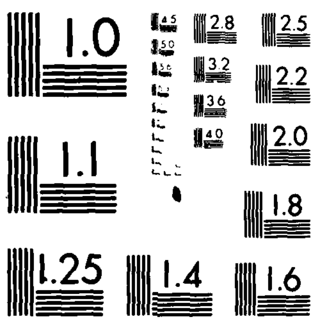
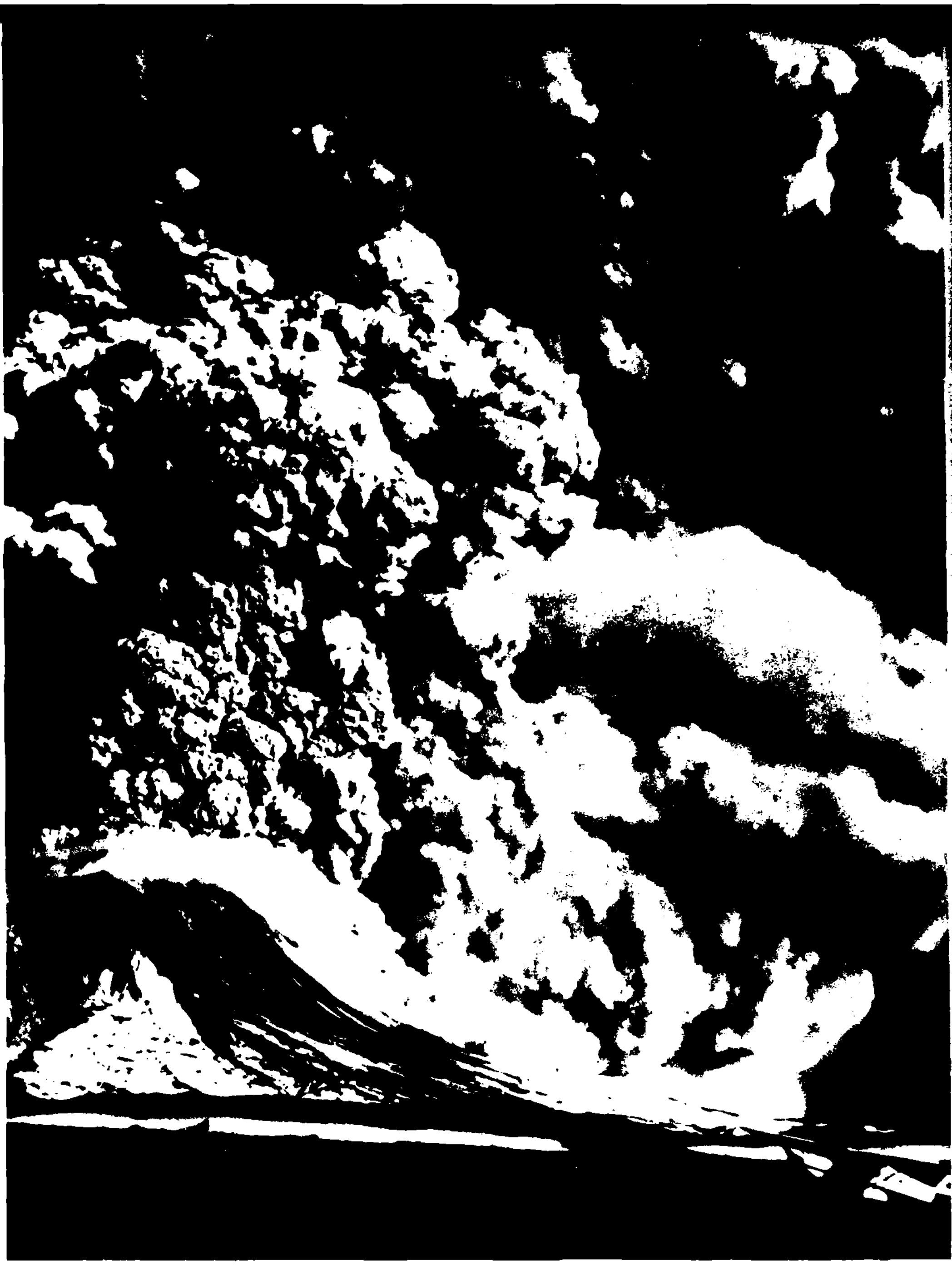


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA



Antarctic Atmospheric Infrasound

FINAL PROGRESS REPORT: GIR 81-4
December 13, 1979-September 30, 1981

Prepared for:

Air Force Office of Scientific Research, NP
Bldg. 410, Bolling Air Force Base, DC 20332

Prepared by:

Charles R. Wilson
John Olson

Antarctic Atmospheric Infrasound

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(3)

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Project Chronology

During the austral summer of 1979-1980 a four microphone infrasonic array was reinstalled at Windless Bight (77°45'S, 167°45'E) on the Ross Ice Shelf near McMurdo Station Antarctica. The analogue infrasonic wave recording system was placed at McMurdo Station for the continuous recording of data on paper chart and slow speed magnetic tape throughout the following year. The infrasonic system installation is described in our report titled:

GIR80-1, Antarctic Atmospheric Infrasound System Installation and Development, 13 Dec 79 to 22 March 1980.

The development of the digital data acquisition and analysis system was completed by October of 1980 as is described in the above listed report GIR80-1. One year of infrasonic data from Windless Bight was analyzed for a background noise study to show that 90% of the time the peak-to-peak noise level is less than 2.5 microbars. These results were presented in our report:

GIR80-2, Noise Analysis for Windless Bight Infrasonic Array, 23 March 1980

The newly developed digital infrasonic system was connected to the existing microphone array at Fairbanks to test its capabilities. Studies were also made of the digital analysis system using data tapes digitized from analogue magnetic tapes from the Fairbanks microphone array on which signals had been recorded from volcanic eruptions and mountain associated infrasound. During October 1980 microbaroms, auroral infrasonic waves and the atmospheric test of a nuclear weapon in China were all recorded and analyzed in real-time by the new system as described in our report:

GIR80-3, Digital Acquisition and Analysis System for Antarctica: Hardware, Software and Testing, 31 October 1980

The new digital system was taken to Antarctica and installed in the Cosmic Ray building at McMurdo station in November of 1980. A new three microphone array with one kilometer spacing was added to the existing 4 microphone array in Windless Bight (see Figure 1). On December 2, 1980 the digital system was operational and began detecting signals immediately as described in our report:

GIR81-2, Digital Infrasonic system Installation in Antarctica, 26 February 1981

The digital system continued to acquire and analyze infrasonic microphone data in real-time throughout the year with the exception of a six week period from 1845 U.T. 11 June 81 to 1327 U.T. 1 August 1981 when the RTG power supply cable developed an open circuit dropping the telemetry system off the air. The repair of this fault was delayed by bad weather conditions causing difficulty in finding the RTG site in the winter night darkness.

The development by Dr. John V. Olson of the Geophysical Institue staff of a data-adaptive polarization filter technique for analyzing time-series data resulted in our testing his methods on infrasonic tapes to see if we could enhance our signal detection capabilities. We were able to show that by use of the polarization filter technique we could detect a synthetic sine wave signal in a random noise background with the digital system when the signal level was -12db with respect to the noise. This work is described in our report:

GIR81-1, Infrasonic Signal Detection Enhancement by a Pure State Filter, 16 February 1981

The great success of the polarization filter technique with infrasonic data led to our proposal to up-grade the Antarctic digital system to include pre-filtering of the microphone outputs with Olson's pure state filter. Upon receipt in April 1981 of a $50,000 increase in the project funding work was begun on developing the hardware and software for the polarization filter digital system.

The training of the winter-over technician for Anatarctica, Mr. Bruce McKibben, an electrical engineer from Oregon State University, was begun in September following the NSF Antarctic Orientation Conference. Mr. McKibben has worked with Dr. Olson writing the software for the off-line frequency-wavenumber analysis in the frequency domain to be used in Antarctic on signals detected by the time domain real-time digital system. He has also worked with the digital design engineer, David Spell, on the new computer hardware.

Bruce McKibben will deploy to Antarctica on December 12 while David Spell and Charles Wilson will leave in late December. The new building that is being built at McMurdo Station for the infrasonics project should be ready by December 15, 1980.

Summary of Infrasonic Data Collected

Analogue Data

Slow speed analogue magnetic tape recording (0.25 inch per minute) and Estertive-Angus paper chart recordings (at 0.75 inches per minute, 1 cm chart displacement equals one microbar of pressure) have been made of the three microphone array (RTG, Erebus and Terror sites) at Windless Bight since 29 January 1980 through December 1, 1980 when an additional microphone (ROSS site) was added to the long period or F array. Analogue recording of these four microphone sites has been continuous since 1 December 1980 until the present time with the exception of the period 11 June 81 to 1 August 81 when the telemetry system lost power as discussed in section 1 of this report.

The analogue data for the period 29 January 1980 to 3 February 1981 is archived at the Geophysical Institute, University of Alaska at Fairbanks. The rest of the analogue data is still at McMurdo Station but will be sent to the University of Alaska in January 1982.

Digital Data

The collection of digital data from a four microphone long-period F array (Erebus, Terror, RTG and Ross sites) and three microphone short-period T array (RTG, Aurora and Vee sites) began on 1 December 1980. The microphone pressure time series data are recorded digitally on 1/2 inch x 2400 feet R165C55 3M computer tape with a format described in our reports GIR81-2 and GIR 80-3. The real-time analysis of the F and T array data are printed out every two minutes with a format described in our report GIR81-2 giving information on signal azimuth, horizontal trace velocity, amplitude, period and cross-correlation between micrphone pairs.

The digital magnetic tapes and analysis printout sheets are archived at the Geophysical Institute for the period 1 December 1980 to 3 February 1981 (tapes 80-1 to 80-7 and 81-1 to 81-6). The digital data for the period 4 February '81 to the present are at McMurdo Station and will be returned to the University of Alaska in January 1982.

Antarctic Infrasonic Signals

No funding was provided for a general analysis of the first year's analogue infrasonic data with the exception of that for certain selected time periods. Analyses were made for the infrasonic waves for the eruption of St. Helens volcano on May 18 of 1980 and for the Chinese atmospheric nuclear test of October 16, 1980.

The analogue chart record data was scaled for February and November of 1980 in a search for auroral infrasonic waves (AIW). The high trace velocity signals that were found and tentativley identified as AIW are listed below in Table I.

Table I

High trace velocity signals from analogue chart data

Date	Time	Azimuth	Trace velocity (m/sec)
1 Feb. 80	0535	138°	505
	1729	115	400
	2221	65	515
5 Feb. 80	1400	97	640
7 Feb. 80	0658	112	568
	0745	129	473
11 Feb. 80	0713	82	860
14 Feb. 80	1816	48	550
5 Nov. 80	1600	108	400
9 Nov. 80	2354	109	345
21 Nov. 80	1005	197	355
	1040	197	355
	0938	150	570
8 Dec. 80	1255	143	647

An infrasonic wave train was observed at 0542 U.T. 19 May at Windless Bight from the 0832 PDT 18 May 1980 explosive eruption of Saint Helens volcano. At 1615 U.T. on the same day the antipodal path infrasonic signal from the St. Helens eruption arrived at the microphone array from an azimuth 180° out of phase with the direct great circle path signal. The great circle path from St. Helens to Windless Bight is 14,562 km long and lies 60° east of north in direction. From the arrival times of the two signals the transit velocity was calculated to be 285 m/sec. for the direct great circle path signal and 286 m/sec. for the antipodal great circle path signal. The observed azimuth of the direct signal varied from 67° to 74° throughout the two hour long wave train while the azimuth of the anitpodal signal varied from 234° to 246°. The direct signal azimuth was from 7° to 14° east of the true azimuth (60°) while the antipodal signal azimuth varied from 6° west to 6° east of the true azimuth (240°). This deflection was caused by transverse winds along the ray path. The data for the St. Helens signals are given in Table II and the signals are shown in Figures 2 and 3.

Table II

Infrasonic Waves from St. Helens Eruptions

Great circle direct path		antipodal path
arrival time	0542 U.T. 19 May 1980	1615 U.T. 19 May 1980
trace velocity	280 to 300 m/sec	320 to 356 m/sec
azimuth of arrival	67° to 74°	234° to 246°
average period	56 sec	70 sec
duration of wave train	0542 to 0750	1615 to 2030
dispersion	long waves first	not clear
transit velocity	285 m/sec	286 m/sec

A large infrasonic signal was received at Windless Bight on 16 October 1980 at 1650 U.T. from the Chinese test of a nuclear weapon in Lop Nor. The detonation time for this event is not known so the transit velocity could not be calculated. The wave train is shown in Figure 4 from the analogue chart records at Windless Bight. The dominant period of the wave train was 30 seconds. At 1700 U.T. the azimuth and trace velocity of the wave were 294° and 350 m/sec. At 1720 U.T. the values of Ø and V_h were 289° and 337 m/sec respectively. A search was made for the anitpodal great circle path signal from Lop Nor but none was found. The azimuth of Lop Nor from Windless Bight is 291°. This compares well with the observed signal azimuth.

Analysis of the digital data has been confined to signals within the period 1 Dec 1980 to 3 February 1981 for which the digital tapes are at the Geophysical Institute. At the end of the austral summer season in Antarctica when we return with the digital data tapes for the period 4 Feb 81 to 1 Feb 82, this data will be analyzed at the Geophysical Institute.

The digital infrasonic data tapes that were recorded at McMurdo Station prior to the closing of the mail in March 1981 have been analyzed. Infrasonic waves have been identified from auroral electrojet motions in the lower ionosphere, volcanic eruptions, marine storm sea wave activity and mountain lee wave sources.

Microbaroms

Standing wave patterns on the sea surface in marine storms produce infrasonic waves in the atmosphere called microbaroms of six-second period that will propagate great distances in the stratospheric sound channel. The storm centers that produce the microbaroms are within the quasi-stationary lows in barometric pressure at sea level that lie off the coast of Antarctica, as shown in Figure 5 for the austral summer period in January. The expanded sensitivity range for the new infrasonic system in Windless Bight down to waves of one second period allows us for the first time to observe microbaroms from the Antarctic marine storms. In Figure 6 the azimuth of arrival (the direction from which the waves have come) and the horizontal trace veloctiy V_h (defined as $V_h = C \sec \alpha$ where C = local sound speed and α = angle between the wave vector and horizontal) are plotted for all the microbarom wave packets for which the correlation coefficient (that is a measure of the coherence between the waveform at pairs of microphones) was greater than 0.6 for the data period 8 December 1980 to 9 May 1981. Because of the very large number of microbarom wave packets observed from the direction of the Ross Sea low (around 1660 in all) and the Bellinghausen Sea low (around 150) not all the data are plotted in the figure but there are enough points to give a general idea of the variation of both number of microbarom events and horizontal trace velocity with azimuth of arrival.

From the location of the low pressure areas shown in Figure 5 it can be determined that these four storm-producing regions subtend the following angles as seen from the Windless Bight infrasonic microphone array; Ross Sea low 15° - 50°; Bellinghausen Sea low 110° - 140°; South Atlantic Ocean low 190° - 240°; South Indian Ocean low 250° - 290°.

The microbarom data, a sampling of which is plotted in Figure 6, show that storms in the Ross and Bellinghausen seas are strong sources of microbaroms infrasound. Microbarom events from the Ross Sea are numerous and at times persist for many days. The Ross sea low is much closer to the infrasonic array than the other barometric lows, thus one would expect more microbarom events from the Ross sea sources.

Propagation conditons play a very important role in determining whether or not microbaroms are observed from a particular source. The horizontal trace velocity measured for a particular microbarom wave packet is equal to the scalar sound speed at the height of reflection of the ray path plus the component of the wind speed at the reflection level in the direction of propagation of the wave.

For this reason the average trace velocity seen for the microbaroms from the Ross sea (about 350 m/sec) is higher than that for microbaroms from the Bellinghausen sea (about 300 m/sec) because the propagation path from the Ross sea storms to the infrasonic microphone array is, on the average, parallel to the stratospheric winds while the propagation path from the microbarom producing storms in the Bellinghausen sea to Windless Bight is anti-parallel to the stratospheric flow. Thus one would expect that the trace velocity of microbaroms from the Bellinghausen sea would be diminished with respect to those from the Ross sea.

Although the above statistical picture of the variation of microbarom trace velocity as a function of propagation path relative to the mean stratospheric flow is crude, it is however suggestive of the future studies that will be made when the upper air wind data become available. It is anticipated that by studying the seasonal variations in the microbarom trace velocity from the different storm centers around Antarctica we can say something about the seasonal morphology of the mean stratospheric flow.

The analysis of auroral infrasonic waves signals, a mini-eruption air wave from Mt. Erebus and an unidentified infrasonic signal from

107° azimuth are all described in our report GIR81-2. Additional high trace velocity auroral signals that have been abstracted from the signal list summaries that were sent by telex from Antarctica during the winter night are listed in Table III below.

All of the data tape summary sheets are reproduced below for the period 8 December 1980 to 1 October 1981. The items listed for each signal where the cross-correlation coefficient was greater than 0.6 are: data block number, date-time, T or F array, maximum and minimum amplitude in microbaroms, period in seconds, correlation coefficient, azimuth, and horizontal trace velocity.

Table III

Digital system high trace velocity signals (F array)

Date	Time Z	Azimuth	Trace velocity(m/sec)	Period (sec)
9 Dec 80	0130	143°	644	33
16 Dec 80	1715	65°	644	33
14 Dec 80	1801	73°	675	31
19 Dec 80	2117	343°	356	33
23 Jan 81	0446	60°	337	28
1 Feb 81	0012	117°	446	29
10 Feb 81	1916	353°	413	28
11 Feb 81	0507	353°	415	28
16 Feb 81	0700	280°	373	31
17 Oct 81	0657	220°	458	36
14 Nov 81	1439	138°	537	38
17 Nov 81	1354	120°	490	35
	1609	79°	590	31
18 Nov 81	1339	126°	459	28

80-4

FOR CHARLES WILSON GEOPHYSICAL INSTITUTE
SUBJ: INFRASOUND REPORT
1. TAPE 80-4, 8 DEC 80, 0215Z TO 12 DEC 80, 2234Z, 3487 BLCKS
2. BLK 424, 8 DEC 80, 1622Z, T, MAX-0.3, MIN-0.13
P 4.3, R 0.64, A Z 25.8, V 354.45 SIMILAR BLKS UP TO 1044
3. BLK 868, 9 DEC 80, 0712Z, T, MAX 0.4, MIN-0.4
P 4.8, R .66, AZ 112, 290.8
4. BLK 1044, 9 DEC 80, 1304Z, F, MAX 0.9, MIN-0.8
P 32.6, RO. 72, AZ143, V644, BLK 1045 SIMILAR
auroral signal
5. BLK 1067, 9 DEC 80, 1350Z, T, MAX 0.2, MIN-0.2
P 4.5 RO.68, AZ16, V361. 40 SIMILAR BLKS UP TO BLK 1325.
6. BLK 1440, 10 DEC 80, 0217, T, MAX 0.5, MIN-0.5 P
P 4.8, RO.68, AZ35, V369. 14 SIMILAR BLOCKS UP TO 2709
DAVID FULLERTON
NSF REP ANTARCTICA

80-5

PASS CHARLEES WILSON
SUBJ: INFRASOUND REPORT
1. TAPE 80-5, 12 DEC 80 2254Z TO 19 DEC 80 1139Z.
4699 BLKS. SIGNALS.
2. BLK 11, 12 DEC 80, 2314Z, T, MAX 1.4, MIN 2.0
P 3.6, R .83, AZ82, V 314
3. BLK 461, 13 DEC 80, 1415Z, T, MAX 0.2, MIN 0.3
P 4.5, R .62, AZ 39, V348
4. BLK 449, 13 DEC 80, 1531, T, MAX 0.2, MON 0.2
P 4.7, R.68, AZ 44, V 357. 121 SIMILAR BLKS TO 3971
5. BLK 584, 13 DEC 80, 1821Z, T, MAX 0.8, MIN 1.4
P 4.0, R 0.73, AZ 81, 342
6. BLK 1293, 14 DEC 80, 1801, F, MAX 0.8, MIN 0.8
P 30.8, R 0.62, AZ 73, V 675
7. BLK 2709, 16 DEC 80, 1715Z, F, MAX, 1.1, MIN 0.7
P 21, R .67, AZ 65, V 644
8. BLK 3971, 18 DEC 80, 1122Z, T, MAX 0.4, MIN, 0.4
P 4.8, R 0.65, AZ 334, V 406
9. DATA LOST 19 DEC FROM 1142Z TO 1832 DUE TO POWER FAILURE.
10. BUG DETECTED IN PROGRAMMING. WHEN FARRAY EVENT PRINTOUT IS MORE THAN TWO MINUTES, ADDITONAL PRINTOUT OF BLK IS SOMEWHAT SCRAMBLED.
I BELIEVE THIS NEEDS CORRECTION.
DAVID FULLERTON
NSF REP ANTARCITICA

80-5A

FAIRBANKS AK TELEX OF 35414
PASS CHARLES WILSON
SUBJ: INFRASOUND REPORT
1. TAPE 80-5 ADDENDA
2. OBSERVED SEVERAL SIGNALS WITH TIME AND AZIMUTH RANGES INDICATED. COMPREHENSIVE DOCUMENTATION FOLLOWS:
3. BLK 1832, 15 DEC 80, 1140Z, I, MAX 0.2, MIN 0.3
P 4.7, R0.640.22, AZ 219, V348
4. BLK 1841, 15 DEC, 1218Z, I, MAX 0.3, MIN 0.3
P 4.5, R 0.58, 0.37, AZ 236, 277
5. BLK 1900, 15 DEC, 1416Z, I, MAX 0.3, MIN 0.3
P 4.7, R0.48, 0.48, AZ 214, V337
6. BLK 1901, 15 DEC, 1418Z, I, MAX 0.4, MIN 0.3
P 4.7, R0.51, 0.51, AZ 205, V338
7. BLK 1902, 15 DEC, 1420, E, MAX 1.0, MIN 1.0
P 16.0, R0.45, 0.60, 0.62, AZ 205, V332
8. BLK 1902 SIGNAL IS CLEARLY SEEN ON PAPER TAPE. SIGNAL COMMENCES AFTER 1414Z AND ENDS BEFORE 1419Z. AZ USING PAPER TAPE IS 209.
DAVE FULLER
FM NSF REP ANTARCTICA MCMURDO ANTARCTICA

80-6

PASS CHARLES WILSON
SUBJ: INFRASOUND REPORT
1. TAPE 80-6, 19 DEC 80 1831Z TO 26 DEC 1250Z.
4869 BLKS, SIGNALS.
2. BLK 84, 19 DEC, 2117Z, E, MAX 1.6, MIN 1.2
P 337, R3.69, AZ 343, V356.
3. BLK 1115, 21 DEC, 0741Z, T, MAX 0.6, MIN 0.6
P 4.7, R0.63, AZ 354, V320
4. BLK 1772, 22 DEC, 0536Z, I, MAX 0.6 MIN 0.6
P 4.7, R0.64, AZ 163, V351. 2 SIMILAR BLKS TO 1787
5. BLK 2428, 23 DEC, 0030Z, I, MAX 0.3, MIN 0.3
P 4.1, R0.64, AZ 30, V353. 129 SIMILAR BLKS TO 4867
6. BLK 2738, 23 DEC, 1350Z, I, MAX 0.4, MIN 0.4
P 4.5, R0.66, AZ 221, V423
FULLERTON
NSF REP ANTARCTICA MCMURDO ANTARCTICA

80-7

1. tape 80-7; 26Dec80 1309Z to 1Jan81 0624Z; 4115 blks signals

2. blk 2; 26Dec80 1311Z; T; max. 0.5; min. 0.47; p. 4.3; r. 0.72; az. 20.7; v 350.2.

3. blk 35; 26Dec80 1417Z; T; max. 0.4; min. 0.3; p. 4.1; r. 0.66; az. 29.8; v 353.8.

4. blk 38; 26Dec80 1423Z; T; max. 0.4; min. 0.4; p. 4.2; r. 0.72; az. 29.8; v 353.8.

5. blk 52; 26Dec80 1451Z; T; max. 0.5; min. 0.5; p. 4.4; r. 0.71; az 25.4; v 337.8.

6. blk 163; 26Dec80 1833Z; T; max. 0.4; min. 0.5; p. 4.6; r. 0.7; az 114.8; v 273.9.
   note: this signal had 34 entries with an az of 6.8 to 237 and a v of 254.5 to 442.0.

7. blk 173; 26Dec80 1853Z; T; max. 0.4; min. 0.4; p. 4.3; r. 0.65; az. 20.7; v 350.2.

8. blk 181; 26Dec80 1909Z; T; max. 0.4; min. 0.4; p. 4.1; r. 0.67; az. 29.8; v 353.8.

9. blk 182; 26Dec80 1911Z; T; max. 0.4; min. 0.5; p. 4.4; r. 0.67; az.25.4; v 337.8.

10. blk 188; 26Dec80 1923Z; T; max. 0.4; min. 0.3; p. 4.1; r. 0.63; az. 25.0; v 369.8.

11. blk 199; 26Dec80 1945Z; T; max. 0.5; min. 0.4; p. 4.3; r. 0.67; az. 20.7; v 350.2.

12. blok 215; 26Dec80 2017Z; T; max. 0.4; min. 0.5; p. 4.6; r. 0.68; az. 25.0; v 369.8.

13. blk 298; 26Dec80 2303Z; T; max. 0.4; min. 0.5; p. 4.8; r. 0.69; az. 22.85; v 360.

14. blk 1696; 28Dec80 2142Z; T; max. 0.5; min. 0.5; p. 4.4; r. 0.68; az. 38.9; v 348.3.

15. blk 1763; 28Dec80 2356Z; T; max. 0.5; min. 0.5; p. 4.0; r. 0.65; az. 34.2; v 336.9.

16. blk 1766; 29Dec80 0002Z; T; max. 0.4; min. 0.4; p. 4.0; r. 0.63; az. 34.2; v 336.9.

17. Blk 4053; 1Jan81 0420Z; F; max. 1.0; min. 1.1; p. 23.4; r. 0.69; az. 28.2; v 327.0.

81-1, 81-2

PASS CHARLES WILSON
SUBJ: INFRASONIC REPORT
1. TAPE 81-1, 01 JAN 81, 0635Z TO 07 JAN 81, 2228Z, 4793 BLKS.
SIGNALS:
2. BLK 3530, 06 JAN 81, 0422Z, T, MAX 0.7, MIN 0.6
P 4.9, 0.69, AZ 98, V313, 6 SIMILAR BLKS TO 3862
3. BLK 3862, 06 JAN 81, 1525Z, T, MAX 0.5, MIN 0.5
P 4.8, R 0.61, AZ 301, V259
4. BLK 3884, 06 JAN 81, 1609Z, T, MAX 0.4, MIN 0.5
P 4.3, R 0.66, AZ21, V350, 11 SIMILAR BLKS TO 4724
5. BLK 4249, 06 JAN 81, 2139Z, T, MAX 0.7, MIN 0.7
P 4.7, R 0.69, AZ 53, V339
6. BLK 4649, 07 JAN 81, 1740Z, T, MAX 0.5, MIN 0.6
P 43, R 0.70, AZ 5, V374
7. STATION RUN BY SATTRACK JAN 2- JAN 3 WHILE I WAS AT SOUTH POLE.
8. ERROR MESSAGES APPREARED BLKS 4678 TO 4793. BELIEVE ATTRIBUTABLE
TO LOW HUMIDITY. PROBLEM CORRECTED BY RESTART. COMPLETE REPORT
INCLUDED W/PRINTOUT DATA.
9. TAPE 81-2, 07 JAN 81, 2319Z TO 8 JAN 81, 0421Z
152 BLKS. NO SIGNALS
10. CLOCK ON TAPE 81-2 AROUND 15 SECONDS SLOW. ALSO F ARRAY SET
TO RUN WITH ONLY THREE PHONES. PROBLEM CORRECTED ON 81-3.
DAVID FULLERTON
NSF REP ANTARCTICA MCMURDO ANTARCTICA

81-3

PASS CHARLES WILSON
SUBJ: INFRASONIC REPORT
1. TAPE 81-3, 8 JAN 81, 0454Z TO 14 JAN 81, 2259Z.
4859 BLKS, SIGNALS:
2. BLK 101, 8 JAN, 0814Z T, MAX 0.7, MIN 0.6
P 4.6, R 0.61, AZ 12, V 339
3. BLK 403, 8 JAN, 1819Z, T, MAX 0.8, MIN 0.7
P 4.4, R0.67, AZ25, V 370, 12 SIMILAR BLKS TO 1039
4. BLK 1039, 9 JAN, 1532, T, --/ 0.6, MIN 0.6
P 44, AZ 237, V 423
5. BLK 2296, 11 JAN, 0925, T, MAX, 0.4, MIN 0.4
P 4.5, R 0.64, AZ 133, V 307
6. BLK 3187, 12 JAN, 1512Z, T, MAX 0.7, MIN, 0.6
P 4.4, R 0.77, AZ 30, V354. 30 SIMILAR BLKS TO 4502
7. BLK 4777 14 JAN, 2015Z, T, MAX 1.0, MIN 0.9
P 4.4, R 0.66, AZ 301, V259
8. THE F ARRAY WAS SET TO RUN W/3 MIKES BY MISTAKE. THERE IS NO
PROBLEM WITH EQUIPMENT.
DAVID FULLERTON

Best

81-4

PASS CHARLES WILSON
SUBJ: INFRASOUND REPORT
1. TAPE 81-4, 14 JAN 81, 2315Z TO 21 JAN, 1404Z.
4761 BLKS, SIGNALS:
2. BLK 13, 14 JAN, 2339Z, T, MAX 1.0, MIN 1.0
P 4.9, R 0.70, AZ 35, V 369. 175 SIMILAR BLKS TO 4534
3. BLK 104, 15 JAN, 0241Z, T, MAX 0.9, MIN 0.9
P 4.8, R 0.67, AZ 301, V 259
4. BLK 2203, 18 JAN, 0043Z, T, MAX 0.7, MIN 0.7
P 4.8, R 0.76, AZ 5, V 374
5. BLK 2458, 18 JAN, 0914Z, T, MAX 0.4, MIN 0.4

81-5

FOR CHARLES WILSON
SUBJ: INFRASONIC REPORT
1. TAPE 81-5, 21 JAN 81, 1440Z TO 28 JAN, 0517Z.
4755 BLKS, SIGNALS:
2. BLK 881, 22 JAN 81, 2001Z, T, MAX 0.5, MIN 0.5
P4.5, R 0.63, AZ 10, V369
3. BLK 1139, 23 JAN, 0438Z, T, MAX 0.7, MIN 0.7
P4.9, R 0.69, AZ 80, V375
4. BLKS 1143-1146, 23 JAN, 0446, E, MAX 1.0, MIN 0.8
P28, R 0.68, AZ 60, V337

5. BLK 1540, 23 JAN, 1801, T, MAX 0.4, MIN 0.4
P4, R 0.62, AZ 34, V337. 265 BLKS SIMILAR UNTIL 4697
6. BLK 3451, 26 JAN, 0946,TMAX 0.7, MIN 0.9
P4.7, R 0.77 AZ 149, V386
7. THE DELAY IN TAPE 81-3 WAS NOT AT THIS END. DAVID FULLERTON.
NSF REP ANTARCTICA MCMURDO ANTARCTICA

81-6

PASS CHARLES WILSON
SUBJ CLN INFRASOUND REPORT
1. TAPE 81-6, 28 JAN, 0547 TO 03 FEB, 2030
4758 BLOCK. SIGNALS CLN

2. BLK 304, 28 JAN, 1554Z, T, MAX 0.4, MIN 0.3
P 4.3, R 0.62, AZ 34, V 337.210 BLKS SIMILAR TP 4757
3. BLK 1992-1994, 31 JAN, 0013Z, E, MAX 1.0, MIN 1.1
P 32.8, R 0.70, AZ 31, V349.BLKS 2037, 2076, 2083, 2106, 2112, 2133,
2155 SIMILAR ENDING AT 0539Z.
4. BLK 2711-2712, 01 FEB, 0012Z, E, MAX, 0.8, MIN 0.9
P 28.9, R 0.62, AS 117, V 446
5. BLK 2953 01 FEB, 0817Z, T, MAX, 0.6, MIN 0.6
P 4.7, R 0.64, AZ 111, V 335.2 BLKS SIMILAR TO 3628.
FULLERTON
NSF REP ANTARCTICA

81-7

PASS CHARLES UILSON
SUBJ: INFRASONIC REPORT
1. TAPE 81-7 03 FEB, 2043Z TO 10 FEB, 1310Z
4810 BLKS. SIGNALS
2. BLK 1, 03 FEB 2043Z, T, MAX, 1.5, MIN 1.5
P4.9, R 0.75, AZ 30, V 354
3. BLK 4349, 09 FEB, 2147Z, T, MAX, 0.6, MIN 0.6,
P 4.0, 4R 0.74, AZ 351, V 343. BLK 4361 SIMILAR
4. ALL ITEMS WERE RECEIVED EXCEPT FOR 16 CASES OF PRINTOUT PAPER.
ONLY 4-5 CASES WERE RECEIVED. I BELIEVE QUANTITIES ON HAND OF ALL
MATERIALS ARE SUFFICIENT.
DAVID FULLERTON

NSF REP ANTARCTICA MCMURDO

81-8

USARP NR 1203
PASS TO C. WILSON
SUBJ: INFRASOUND REPORT
1. TAPE 81-8 10 FEB 1326Z TO 17 FEB 0853Z.4900BLKS.SIGNALS.
2. BLK 177,10 FEB 1916Z,E,MAX 0.9,MIN 0.9,P28,R 67,AZ 353,V 413
3. BLK 32C 11 FEB 0008Z,T,MAX 0.8,MIN 0.8,P4.5,R69,AZ 20,V 384.
BLK 221 SIMILAR UNTIL 4764.
4. BLK 500 11 FEB 0603Z,T,MAX 0.9,MIN 0.8,P4.6,R75,AZ 71,V 361.
5. BLK 531 11 FEB 0705,E,SIMILAR TO BLK 177.
6. BLK 1595 12 FEB 1835Z,T,MAX 0.8,MIN 0.8,P5.0,R64,AZ 305,V 258.
7. BLK 3476 15 FEB 0921Z,T,MAX 0.6,MIN 0.5,P4.7,R66,AZ 105,V 304.
8. BLK 4125 16 FEB 0700Z,E,MAX 1.0,MIN 0.9,P31,R65,AZ 280,V 373.
FULLERTON SENDS
MCMURDO STATION

81-9

PASS TO C. WILSON
SUBJ: INFRASOUND REPORT
1. TAPE 81-9, 17 FEB, 0902Z TO 23 FEB, 2329Z 4750 BLKS
SIGNALS.
2. BLK 167, 17 FEB, 1434Z, T, MAX 2.1, MIN 2.6, P4.9, R80,
AZ 342, V 342.BLKS 2479 SIMILAR.
3. BLK 1073, 18 FEB, 2048Z, T, MAX 0.9, MIN 0.9, P4.9, R70,
AZ 343, V359. BLKS 1439, 1495 SIMILAR.
4. BLK 3380, 22 FEB, 0147Z, T, MAX 1.3, MIN 1.3, P4.3, R72,
AZ 16, V 361. 122 BLKS UP TO BLK 4666 SIMILAR.
FULLERTON SENDS
MCMURDO STATION ANTARCTICA

81-10

PASS TO C. WILSON
SUBJ: INFRASOUND REPORT
1. TAPE 81-10,23 FEB,2340Z TO 2 MAR,1439Z.4766 BLKS.SIGNALS.
2. BLK 88,24 FEB,0234Z,T,MAX 1.1,MIN 1.0,P4.5,R62,AZ 30,V 354.
17 BLKS SIMILAR UP TO 4747.
3. BLK 1723,26 FEB,0907Z,T,MAX 0.8,MIN 0.7,P4.6,R63,AZ 107,V 329.
4. BLK 1759,26 FEB,1019Z,T,MAX 0.7-MIN 0.7,P4.7,R61,AZ 251,V 361.
FULLERTON SENDS
MCMURDO STATION

81-11

SUBJ: INFRASOUND REPORT
1. TAPE 81-11, 2 MAR, 1452Z TO 9 MAR, 0831Z .4846 BLKS.
2. BLK 70, 2 MAR, 1711Z, T, MAX 1.2, MIN 1.1, P4.7, R64, AZ 30, V 324. 145 BLKS SIMILAR TO 3968.
3. BLK 1040, 4 MAR, 0132Z, T, MAX 0.8, MIN 0.8, P5.0, R64, AZ 223, V 328.
4. BLK 2215, 5 MAR, 1644Z, T, MAX 0.7, MIN 0.6, P5.0, R61, AZ 305, V 258. 4 SIMILAR BLKS TO 3074.
5. BLK 2659, 6 MAR, 0733Z, T, MAX 0.5, MIN 0.5, P4.9, R67, AZ 182, V 346. 12 BLKS SIMILAR TO 4343.
6. BLK 3643, 7 MAR, 1623Z, T, MAX 2.1, MIN 2.8, P4.4, R76, AZ 282, V 314. BLK 4192 SIMILAR.
FULLERTON SENDS
MCMURDO STATION ANTARCTICA

81-12

PASS TO C. WILSON
SUBJ: INFRASOUND REPORT
1.TAPE 81-12,9 MAR 0848Z TO 16 MAR 0435Z,4910 BLKS
2.BLK 52,9 MAR,1030Z,T,MAX 0.5,MIN 0.5,P5.1,R65,AZ 240,V 277.
TWO BLKS SIMILAR UNTIL 767,4259 SIMILAR.
3.BLK 796,10 MAR,1119Z,T,MAX 0.8,MIN 0.8,P4.7,R71,AZ 126,V 336.
107 BLKS SIMILAR UNTIL4450.
4.BLK 2285,12 MAR,1300Z,T,MAX 0.6,MIN 0.6,P5.2,R66,AZ 166,V 337.
5.BLK 2336,12 MAR,1442Z,T,MAX 0.5,MIN0.6,P0.7,R68,AZ 313,V 389.
BLKS 2348,2381 SIMILAR.
6.BLK 3512,14 MAR,0556Z,T,MAX 1.2,MIN 1.2,P5.3,R65,AZ 359,V 282.
BLKS 3593,4861 SIMILAR
REGARDS,DAVE FULLERTON
MCMURDO STATION ANTARCTICA

81-13

PASS TO C. LILSON
SUBJ: INFRASONIC REPORT
1. TAPE 81-13.16 MAR.0446Z TO 22 MAR.1935Z,4761 BLKS.
2. BLK 1378.18 MAC,0243Z,I, MAX 0.8.MIN 0.8.P5.1.R65,AZ 39, V 348.
46 BLKS SIMILAR UP TO 4256.
3. BLK 1621.1 MAR,1049Z,I,MAX 0.6.MIN 0.6,P4.9.R61.AZ 127,V 273.
4.BLK 2293.19 MAR,0914Z.I.MAX 0.8,MIN 0.8,P4.9.R69.AZ 242,V 261.
5.BLKS 4702 TO 4761 HAD ERROR MSG AND MAY NOT BE RECORDED ON THE DIDITAL MAG TAPE.REPEAIR OF FAILURE OF TAPE ARM MECHANISM EFFECTED BY D.HONEA AND MYSELF. TAPE 81-14 BEGUN ON 25 MAR.0411Z.
5.RE YOUR MSG OF 2 MAR AND OUR CONVERSATION OF 23 MAR.THE POSITIVE SIGNAL REFFERED TO WAS IN MY ORIGINAL REPORT.
REGARDS, DAVID FULLERTON
MCMURDO STATION ANTARTICA

81-14

FOR C. WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81-14,0412Z,25 MAR TO 1053Z, 30 MAR. 3798 BLKS. BLKS 3664 TO 3798 HAD MAG TAPE WRITING ERROR FLAG AND MAY NOT BE RECORDED.
2. BLK 10,25 MAR, 0430Z,T, MAX 0.7, MIN 0.7, P5.0, R66, AZ 16, V 361.
45 BLKS SIMILAR TO 2219.
3.BLK 114,25 MAR,0648Z,I,MAX 0.7,MIN 0.7,P4.5,R62,AZ 115, V 274.
4.BLK 1103,26 MAR,1658Z,I,MAX 0.9,MIN 0.9,P5.1,R67,AZ 301, V 259.
5.BLK 2245,28 MAR,0704Z,I,MAX 1.0,MIN 1.0,P5.1,R61,AZ 173,V 373
6.BLK 3002,29 MAR,0817Z,I,MAX 1.0,MIN 1.1,P5.3,R66,AZ 119, V 275.
5 BLKS SIMILAR TO 3790.
7. MAG TAPE DRIVE IS HAVING PROBLEMS SIMILAR TO TWO WEEKS AGO. THE ARM LIGHTS ARE OKAY. ANOMILIES ARE NOTED BELOW.
8. TAPE 81-14 WAS BEING USED AT ONE HALF NORMAL RATE. AT BLK 3500 ONLY ABOUT ONE HALF WAS RECORDED BUT MEASURED BLK LENGTH WAS 5.75 INCHES WHICH SEEMS RIGHT.
9. AT APPROX BLK 3664 THE DIGITAL TAPE REWOUND ITSELF THUS THE SUBSEQUENT WRITING ERRORS.
10. ATTEMPT TO LOAD FRESH TAPE ENCOUNTERED PROBLEMS AT BOT. METALLIC BOT WOULD ENTER THE BOT DETECTER RECOIL, ONE HALF INCH, RE-ENTER AND RECOIL AT A RATE OF ABOUT 3 CPS. ADJUSTMENTS OF SEC 10.4 RAISED TP VOLTAGE FROM 8.4 TO 9.0 VOLTS BUT DID NOT CORRECT PROBLEM.
11. RE THE PHONE CONVERSATION WITH DAVID SPELL I ADJUSTED THE VANE POSITIONING AND THIS ELIMINATED THE BOUNCING. HOWEVER I AM NOT CONVINCED THE SYSTEM IS FIXED.
REGARDS, DAVID FULLERTON
MCMURDO STA

81-14.5, 81-15

PASS TO C. WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81-14.5, 30 MAR, 1123Z TO 31 MAR, 0430Z. 514 BLKS.
NO DIGITAL RECORD.
2. BLK 2, 30 MAR, 1125Z, T, MAX 1.0, MIN 0.9, P5.5, R76, AZ 133, V 307.
BLKS 4, 16, 53 SIMILAR.
3. TAPE 81-15, 31 MAR, 0436Z TO 4 APR, 1305Z. 3133 BLKS, BLKS 2939
TO 3133 HAD ERROR MSG AND MAY NOT BE RECORDED.
4. BLK 1108 1 APR, 1732Z, T, MAX 0.6, MIN 0.6, P5.1, R70, AZ 171, V 343.
5. BLK 2263, 3 APR, 0804Z, T, MAX 0.7, MIN 0.7, P5.0, R78, AZ 121, V 293.
6. BLK 2693, 3 APR, 2225Z, T, MAX 0.6, MIN 0.6, P4.9, R70, AZ 008, V 405.
15 BLKS SIMILAR TO 3001.
7. TAPE 81-15.5, 14 APR, 1309Z TO 5 APR, 1104Z. 657 BLKS, NO SIGNALS.
8. TAPE DRIVE CALIBRATIONS NOW CORRECT. SOLDER JOINTS ARE GOOD.
TAPE DRIVE STILL BOUNCES AT BOT. IF LOAD AND ON LINE ARE HELD DOWN
TO SIMULATE BOT THE BOUNCING STOPS. HOWEVER THE CAPSTAN TURNS CW
CONTINOUSLY SLOWLY IN THE RWD DIRECTION.
9. SINCE THE PROBLEM OFBOUNCING EXISTED BEFORE I ATOEMPTED THE
INITIAL REPAIRS, IT IS LIKELY THAT THE RVEAL CAUSE OF THE TAPE DRIVE
PROBLEM HAS NOT BEEN FOUND. IN RETROSPECT IT APPEARS THAT THE ARM
LAMP MAY NOT HAVE BEEN FAULTY.
REGARD, DAVE FULLETON
MCMURDO STATION

PASS TO C. WILSON
SUBJ: INFRASONICS REPORT
81-16 1. TAPE 81-16, 5 APR, 1110Z TO 5 APR, 2201Z. 326 BLKS. BLKS 108 TO
326 WERE ACCUMPANIED BY MAGTAPE ERROR FLAG AND MAY NOT BE RECORDED.
2. BLK 74, 5 APR, 1337Z, T, MAX 0.6, MIN 0.6, P5.0, R63, AZ 189, V 318.
13 BLKS SIMILAR TO 239.
3. BLK 206, 5 APR, 1801Z, T, MAX 0.5, MIN 0.5, P5.6, R64, AZ 30, V 324.
4. TAPE 81-16.5, 6 APR, 0255Z TO 9 APR, 1020Z. DIGITAL NOT RECORDED.
PROGRAM FOR THIS TAPE SUSPECT AS ONLY THREE POINTS IN F ARRAY
ANALYSED AND DATA FROM MIC 1, 2, 3, NOT PRINTED OUT. PROGRAM RELOADED
ON 9 APR. TOTAL 2394 BLXS.
5. BLK 22, 6 APR, 0307Z, T, MAX 0.6, MIN 0.6, P5.2, R67, AZ 201, V 350.
6. BLK 1603, 8 APR, 0752Z, T, MAX 0.9, MIN 1.0, P5.4, R69, AZ 3, V 281.
7. BLK 1826, 8 APR, 1519Z, T, MAX 0.6, MIN 0.6, P4.9, R64, AZ 25, V 338.
BLKS 2177, 2191 SIMILAR.
8. BLK 2390, 9 APR, 1008Z, T, MAX 0.7, MIN 0.7, P5.1, R66, AZ 131, V 270.
9. DISCUSSION OF TAPE DRIVE PROBLEMS: AFTER INVESTIGATION OF THE
CAPSTAN CONTROL CIRCUITY IT WAS FINALLY POSSIBLE TO ZERO THE CAPSTAN
CONTROL VOLTAGE PER PARA 10.2.1. HOWEVER NO DEFINITE COMPONENT
FAILURE WAS FOUND. AS OF 1120Z, APR 9 THE DIGITAL DATA IS APPARENTLY
BEING RECORDED. SINCE NO DEFINITE FAILURE HAS BEEN FOUND THE TAPE
PROBLEM MAY REOCCUR.
10. FOLLOWING IS A SUMMARY OF THE SITUATION WITH THE CAPSTAN CONTROL
TO DATE: A) TP15 GAVE A VOLTAGE OF -1.4V THAT COULD NOT BE AFFECTED
BY THE ZEROING POTENTIOMETER.
B) PIN 2, U4 GAVE A CONSTANT -0.09V THAT DID NOT VARY.
PIN 3 WAS A CONSTANT ZERO VOLTS.
C) THE CAPSTAN TURNED CW AT A RATE VARIABLE BY THE ZERO POT
TO A LIMITED DEGREE.
D) LATER THE CAPSTAN CONTROL RESPONDED TO THE CALIBRATION
OF PARA 10.2.
E) IF THE PROBLEM RETURNS I WILL ATTEMPT TO USE QUICK
FREEZE TO LOCATE THE INTERMITTENT COMPONENT.
REGARDS, DAVID FULLERTON
MCMURDO STATION ANTARCTICE

81-17

ASS TO C WILSON
SUBJ: INNRASONICS REPORT
1. TAPE 81-17, 9 APR,1031Z TO 15 APR,0222Z. 4073 BLKS.
2. BLK 98,9 PAR,1345Z,T,MAX 0.8,MIN 0.9,P5.2,R71,AZ 2,V 409.
9 BLKS SIMILAR TO 514.
3. BLK 226,9 APR,1801Z,T,MAX 0.7,MIN 0.7,P5.2,R70, AZ 121,V ~~SWTOM~~ 259
4. BLK 1060,10 APR.2151Z,T,MAX 0.8,MIN 0.9,P5.2,R63,AZ 30.V 354.
5. BLK 1949,12 APR,0330Z,T,MAX 1.2,MIN 1.2,P5.9,R62,AZ 114,V312.
BLK 2095 SIMILAR.
6. BLK 2686,13 APR ,0406Z, T, MAX 0.7, MIN 0,7, MIN 0.9,P4.9,R66,AZ 44,V 358.
BLKS 3767,4028 SIMIAR.
7. TAPE DRIVE APPEARS OKAY. RATE OF USAGE UP ABOUT 15 PER CENT.
REGARDS DAVID FULLERTON
MCMURDO STATION ANTARCTICA

81-18

1. TAPE 81-18, 15 APR,0231Z TO 21 APR,0206Z. 4304 BLKS.
2. BLK 20,15 APR,0309Z,T,MAX 1.0,MIN 0.9,P5.1,R64,AZ 54,V 260.
BLK 463 SIMILAR.
3. BLK 160,15 APR,0749Z,T,MAX 1.1,MIN 1.1,P5.6,R69,AZ 324,V 365.
9 BLKS SIMILAR TO 457.
4. BLK 260,15 APR,1109Z,T,MAX 0.9,MIN 0.9,P4.8,R67,AZ 153,V 367.
BLK 292 SIMILAR.
5. BLK 2929,19 APR,0412Z,T,MAX 1.1,MIN 1.1,P5.2,R67,AZ 292,:.: 291.
6. BLK 3481,19 APR,2237Z,T,MAX 1.3,MIN 1.2,P4.7,R65,AZ 195,V 290.
18 BLKS SIMILAR TO 4297.
7. BLK 3490,19 APR,2255Z,T,MAX 3.7,MIN 3.3,P4.4,R69,AZ 85,V 330.
8. TAPE DRIVE STILL RUNNING OKAY ALBEIT A BIT FAST.
REGARDS,DAVID FULLERTON
MCMURDO STATION ANTARCTICA

81-19A, 81-19B, 81-19C

PASS TO C.WILSON
SUBJ: INFRASONICS REPORT
1. PRINTOUT 81-19A. 26 APR,1236Z TO 27 APR,0347Z.456 BLKS. NO SIG.
2. PRINTOUT 81-19B. 27 APR,1125Z TO 04 MAY,0425Z. 4830 BLKS. SIG.
3. BLK 49,27 APR,1301Z,T,MAX 1.6,MIN 1.5,P5.3,R63,AZ 123,V 314.
4. BLK 701,28 APR,1047Z,T,MAX 1.7,MIN 2.3,P5.6,R68,AZ 169,V 317.
5. BLK 3659,02 MAY,1327Z,T,MAX 1.5,MIN 1.4,P5.1,R63,AZ 117,V 293.
5 BLKS SIMILAR TO 3881.
6. BLK 4648,03 MAY,2227Z,T,MAX 1.2,MIN 1.1,P5.0,R66,AZ 356,V 346.
BLK 4759 SIMILAR
7. BLK 4727,04 MAY,0105Z,T,MAX 1.0,MIN 1.0,P4.9,R61,AZ 222,V 303.
8. BLKS 4827 TO 4833,04 MAY,0425Z,F,MAX 1.5,MIN 1.6,P30,R GREATER THAN 67,AZ APPROX 211,V APPROX 430. AFTER A 15 MIN PRINTOUT I TOOK THE COMPUTER OFF LINE AND RESTARTED IT AS I FEARED THE PRINTOUT MIGHT BE INFINITE. THE AZS APPEARED CONSISTENT. NOTHING DRAMATIC APPEARED ON THE PAPER TAPE AT THIS TIME SO I DOUBT THIS REAL SIGNAL.
9. PRINTOUT 81-19C,04 MAY,0451Z TO 07 MAY,2342Z. 2725 BLKS. SIGNALS.
NOTE: PRINTOUT READS MONTH AS APR AND SHOULD READ MAY.
10. BLK 811,05 MAY,0751Z,T,MAX 1.0,MIN 1.0,P58,R63,AZ 210,V 324.
BLKS 995,1025 SIMILAR.
11. BLK 1675,06 MAY,1240Z,T,MAX 1.5,MIN 1.6,P5.5,R68,AZ 133,V 307.
83 BLKS SIMILAR TO 2725.
12. BLK 2491,07 MAY,1554Z,T,MAX 1.2,MIN 1.2,P5.9,R68,AZ 343,V 269.
BLK 2693 SIMILAR.
13. TAPE 81-20,07 MAY,2346Z TO 14 MAY,1525Z. 4783 BLKS. SIGNALS.
NOTE:PRINTOUT AND TAPE INCORRECTLY READ MONTH AS APR AND SHOULD READ MAY.
14. BLK 05,07 MAY,2354Z,T,MAX 1.3,MIN 1.2,P5.3,R75,AZ 125,V 292.
122 BLKS SIMILAR TO 4135.
15. BLK 978,09 MAY,0822Z,F,MAX 1.7,MIN 1.6,P23,R62,AZ 340, V 354.
9 BLKS SIMILAR UP TO BLK 1092 ENDING 09 MAY,1210Z. SUGGEST THIS SIG MAY REPRESENT ERUPTION OF SAME VOLCANO YOU QUERIED ME ABOUT ON 04 MAY. NO SIGNALS WERE FOUND ON APR 27 TO APR 28.
16. BLK 1062,09 MAY,1110Z,F,MAX 1.8,MIN 1.5,P2[illegible],R75,AZ 337,V 342.
THIS HIGHEST COEEFICIENT SIGNAL OUT OF 10 BLKS RECOREDED.
17. BLK 4751,14 MAY,1415Z,T,MAX 1.2,MIN 1.1,P5.0,R63,AZ 14,V 396.
18. TAPE UNIT CURRENTLY WORKING BUT NOT FIXED. I WILL TRY REPLACING THE U-4 OP AMP THE NEXT TIME IT FAILS.
19. DAVID HONEA AND I RETURNED TO THE RTG SITE ON MAY 16. THE LONG DELAY WAS DUE TO POOR WEATHER AND LOGISTICS PROBLEMS. WE WERE ABLE TO RAISE THE RTG OUTPUT VOLTAGE TO 2.9V AND THE INVERTER TO 25 VOLTS MAKING THE XMTR INPUT VOLTAGE APPROX 11V. THE PROBLEM WAS APPARENTLY CAUSED BY STRESS ON THE RTG OUTPUT CABLE INDUCED BY THE WEIGHT OF THE HANGING CABLE. WE SUSPENED THE CABLE AND RELIEVED THE STRESS. SIGNAL TONES IN CHANNELS 1,2,3 ARE STILL IMPURE DESPITE INCREASED VOLTAGES.
20. PLEASE MAIL SPARE PAPER TIGER RIBBONS TO ME IMMEDIATELY IN CASE WE GET A MID-WINTER AIR DROP. MY SUPPLY WILL PROBABLY LAST UNTIL WINFLY BUT IT WILL BE CLOSE.
21. SORRY ABOUT THE DELAY IN RESPONDING. I WAS WAITING FOR THE OUTCOME OF THE TRIP TO WINDLESS BIGHT AND THE TRIP KEPT BEING POSTPONED.
REGARDS, DAVID FULLERTON
MCMURDO STATION ANTARCTICA

81-21

PASS TO C. WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81-21,14 MAY,1530Z TO 21 MAY,1120Z. 4912 BLKS.
2. BLK 163,14 MAY,2054Z,T,MAX 1.3,MIN 1.1,P5.2,R67,AZ 25,V 338.
36 BLKS SIMILAR UNTIL 4708.Z
3. BLK 710,15 MAY,1509Z,T,MAX 1.0,MIN 1.1,P4.9,R63,AZ 04,V 321.
4. BLK 781,15 MAY,1731Z,T,MAX 0.8,MIN 1.0,P5.0,R64,AZ 101,V 297.
3 BLKS SIMILAR TO 841.
5. BLK 4733,31 MAY,0522Z,MAX 1.0,MIN 1.1,P4.9,R68,AYV127,V 273.
6. ALL EQUIPMENT IS WORKING AS IN LAST REPORT. A MID-WINTER AIR
DROP IS SCHEDULED FOR 21 JUNE.
REGARDS, DAVID FULLERTON
FM MCMURESWJTATION ANTARCTICA

GEOPH INST FBK

ALASKAINFO AHG

81-22

PASS TO C. WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81/22,22 MAY,1132Z TO 28 MAY,0705Z. 4903 BLKS.
2. BLK 809,22 MAY,1429Z,T,MAX 0.9,MIN 0.9,P5.3,R68,AZ 16,V 361.
8 BLKS SIMILAR UNTIL 1858.
3. EQUIPMENT STATUS THE SAME AS LAST REPORT.
REGARDS,DAVID FULLERTON
MCMURDO STATION ANTARCTICA

GEOPH INST FBK

81-23

ASS TO C WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81/23,28 MAY 0717Z TO 04 JUN 0324Z. 4920 BLKS.
2. NO SIGNALS RECORDED.
3. EQUIPMENT STATUS APPEARS UNCHANGED. PROGRAM WOULD NOT ACCEPT A
TIME CHANGE ON 04 JUNE. I RELOADED THE PROGRAM AND WAS ABLE TO
INSERT THE CORRECT TIME. I SUGGEST PROGRAM BE MODIFIED NEXT YEAR
TO ALLOW TIME CORRECTIONS WITHOUT A RE-INSERTING OF ALL PARAMETERS.
REGARDS, DAVID FULLERTON
MCMURDO STATION
NTARCTICA

81-24 , 81-24.5

PASS TO C.WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81/24,04 JUN,0356Z TO 10 JUN,2249Z. 4883 BLKS. THE COMPUTER CONTINUES TO HAVE DIFFICULTIES ACCEPTING A TIME. WHILE TIME OF DAY FOR THIS TAPE ARE CORRECT, THE MONTH AND DATE ARE INCORRECT. THE MONTH IS ERRONEOUSLY GIVEN AS JULY INSTEAD OF JUNE. THE DAY OF THE MONTH IS THREE DAYS BEHIND THE CORRECT DATE. TIMES GIVEN IN THIS REPORT ARE CORRECT.
2. BLK 1909,06 JUN,1936Z,T,MAX 0.6,MIN 0.7,-5.0,R64,AZ 128,V 256.
3. BLK 2779,08 JUN,0037Z,T,MAX 0.7,MIN 0.7,P4.9,,68 - 36,V 325.
4. BLK 3614,09 JUN,0429Z,T,MAX 0.7,MIN 0.7,P5.4,R67,AZ 125,V 292.
33 BLKS SIMILAR TO 4112.
5. TAPE 81/24.5- REF PARA 1. SAME TIME PROBLEM. 10 JUN,2300Z TO 11 JUN-0122Z. 72 BLKS. NO SIGNALS. AN END OF FILE IS FOLLOWED BY TAPE 81/25.
REGARDS,FULLERTON
MCMURDO STATION
+
GEOPH INST FBK

81-25A

PASS TO C. WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81/25A,11 JUN, 0127Z TO 14 JUN,0211Z. 2121 BLKS.
2. BLK 471,11 JUN,1707Z,F,MAX 1.4,MIN 1.2,P20,R66,AZ 342,V 368.
3. TPAE 8/25B,14 JUN,0913Z TO 17 JUN,2322Z. 258 BLKS. TAPE 81/25A IS FOLLOWED BY EOF AND THEN TAPE 81/25B.
4. BLK 127,14 JUN,1325Z,T,MAX 1.2,MIN 1.1,P6.1,R68,AZ 90,V 346.
5. WE ARE AGAIN EXPERIENCING PROBLEMS WITH TELEMETRY. RADIO SIGNALS WERE LOST AT ABOUT 1845Z,11 JUN AND HAVE SINCE BEEN RECEIVED ONLY SPORADICALLY. SPECIFICALLY FROM 0700Z TO 1530Z,14 JUN AND AGAIN AT 0700Z TO 1330Z, 17 JUN. TEMPERATURE AND WIND HAVE NOT BEEN ABNORMAL.
6. I THINK THE PROBLEM INVOLVES THE CABLE CONNECTING THE RTG AND THE INVERTER. PREVIOUSLY WE INSERTED SHIMS IN THE CONNECTOR AS SUGGESTED BUT WITHOUT EFFECT SO THE FAULT PROBABLY IS NOT THERE.
7. THE FLAGGED ROAD TO THE RTG SITE HAS BEEN COMPLETELY COVERED BY DRIFT AND NO LONGER EXISTS. FOR THAT REASON DAVID HONEA AND I FEEL THAT SAFETY DICTATES WE WAIT FOR MORE LIGHT BEFORE ATTEMPTING TO REACH THE SITE FOR REPAIRS.
8. CLOCK SEEMS TO BE WORKING NORMALLY NOW.
REGARDS, DAVID FULLERTON
MCMURDO STATION

81-27, 81-28

PASS TO C.WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81/27. NO EVENTS,BAD DATA JUNE TO AUG.
2. TAPE 81/28. 21 AUG,1327Z TO 08 AUG,2458Z. 4782 BLKS.
3. BLK 049. 01 AUG,1533Z,T,MAX 1.1,MIN 1.2,P5.1,R66,AZ 123, V 314.
85 BLKS SIMILAR TO BLK 4778.
4. BLK 1637. 05 AUG,2002Z,T,MAX 1.1,MIN 1.2,P4.9,R61,AZ 354, V 323.
5. ALL EQUIPMENT WORKING NORMALLY.
REGARDS, FULLERTON
MCMURDO STATION ANTARCTICA

81-29

PASS TO C.WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81/29, 08 AUG, 0505Z TO 15 AUG, 0129Z. 4923 BLKS.
2. BLK 77, 08 AUG,0738Z,T,MAX 0.9,MIN 0.9,P5.2,R68,AZ 131,V 332.
35 BLKS SIMILAR UNTIL 568.
3. BLC 236, 08 AUG,1256Z,T,MAX 1.0,MIN 1.0,P5.1,R71,AZ 352,V 298.
4. AFTER 09 AUG,0032Z NO EVENTS WERE RECORDED. HOWEVER, EQUIPMENT
OPERATION APPEARS NORMAL.
REGARDS, FULLERTON
MCMURDO STATION ANTARCTICA

81-30

UNCLAS USARP NR 1530
PASS TO C. WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81/30. 15 AUG,0129Z TO 21 AUG,1456Z. 4720 BLKS.
2. BLK 2612, 18 AUG,1636Z,T,MAX 4.2,MIN 4.7,P4.5,R86,AZ 86,V 304.
SIGNAL HIGHLY TIME LOCALIZED AND DID NOT APPEAR IN NEARBY READOUTS.
3. BLK 2962,19 AUG,0417Z,T,MAX 0.8,MIN 0.7,P5.2,R64,AZ 125,V 292.
TEN BLKS SIMILAR UNTIL 4312.
4. BLK 4273,21 AUG,0001Z,T,MAX 0.7,MIN 0.8,P5.0,R62,AZ 359,V 375.
REGARDS,FULLERTON
MCMURDO STATION

81-31

*7SUBJ: INFRASONICS REPORT
1. TAPE 81/31, 21 AUG 1508Z TO 28 AUG 1117Z. 4991 BLKS
2. BLK 311, 22 AUG 0128Z, T, MAX 1.0 MIN 0.9 P 4.9, R 63, AZ 123,
V 314. 18 BLKS SIMILAR UNTIL BLK 841
3. BLK 584, 22 AUG, 1034Z, T, MAX 0.9, MIN 0.9 P 5.2, R 68,
AZ 353, V 373.
REGARDS FULLERTON
MCMURDO STATION

81-32

FOR : C. WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81/32, 28 AUG, 1129Z TO 4SEPT, 0536Z, 4860 BLKS.
2. BLK 122, 28 AUG, 1531Z, T, MAX 0.6, MIN 0.7 P 4.6, R 62,
AZ 119, V314. 29 BLKS SIMILAR UNTIL 2278.
3.BLK, 3884, 2 SEPT, 21023, T,QMAX 0.8, MIN 0.7P 4.6, R 66,
AZ 60, V 370. 4 BLKS SIMILAR UNTIL 4534.
4. BLKS 4632, 4633, 3 SEPT, 2200, F, MAX 9.0, MIN 9.7 P 86,
R 63, AZ 23, V 358.
REGARDS FULLERTON
MCMURDO STATION SNTARCTICA

81-33

PASS TO C. WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81/33, 4 SEP, 0545Z TO 10 SEP 2345Z. 4857 BLKS.
2. BLK 553, 5 EP 0009Z, T, MAX 0.6, MIN 0.6 P 5.1, R 67, AZ55,
V 369. APPROX 250 BLKS SIMILAR UNTIL 1879.
3. BLK 2732, 8 SEP, 0051Z, T, MAX 1.1, MIN 1.1 P 52, R 69, AZ 121,
V 293. SEVERAL HUNDRED BLKS SIMILAR UNTIL 4816.
4. BLK 4118, 9 SEP 2306Z,T, MAX 1.8, MIN 1.8 5.3, R63, AZ 357,
265. 7 BLKS SIMILAR UNTIL 4463.
REGARDS FULLERTON
MCMURDO STATION

81-34

FOR: C. WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81/34 10 SEP, 2375Z TO 17 SEP, 2004Z. 4920 BLKS.
2. BLK 151, 11 SEP, 0457Z, T, MAX 1.2, MIN 1.2
P 4.4, R67, AZ 98 V 341. ANOTHER ENTRY OF IDENTICAL R WAS
R67, AZ 258, V466
3. BLK 2102, 13 SEP, 2203Z, T, MAX 0.8, MIN 1.0
P 4.9, R67, AZ 121, V 293. 14 BLKS SIMILAR UNTIL 2722.D
4. BLK 2282, 14 SEP, 0403Z, T, MAX 0.8, MIN 0.9
P 5.3, R 64, AZ 238, V 296. BLK 2564 SIMILAR
5. HUMIDIFIER IS TIRING. HUMIDITY IS DOWN TO 20 PERCENT. I WILL CHECK
OUT THE MOTOR.
REGARDS FULLERTON
MCMURDO STATION ANTARCTICA

81-35

PASS TO: C. WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81/35 17 SEP 2014Z TO 24 SEP 1255Z, 4817 BLKS.
2. BLK 1799, 20 SEP 0813Z, T, MAX 0.6, MIN 0.6
P. 5.3, R 65, AZ 190, V 295. BLKS 1870 SIMILAR
3. BLK 3953, 23 SEP, 0805Z, T, MAX 1.3, MIN 1.2
P. 6.3, R 71, AZ 179, V 322. 5 BLKS SIMILAR UNTIL 4168.
4. TAPE 81/34.5, 24 SEP 1324Z TO 24 SEP 2306Z, NO EVENTS. NOT RECORDED ON MAGTAPE. I RECEIVED A MAGTAPE WRITING ERROR WHEN I STARTED TAPE 81/35 AND THE TAPE DID NOT MOVE OFF THE BOT. HOWEVER, I TRIED AGAIN AT 2330Z AND HAD NO PROBLEM.
REGARDS FULLERTON
MCMURDO STATION

81-36

FOR: C. WILSON
SUBJ: INFRASONICS REPORT
1. TAPE 81/36 2319Z SEP 24 TO 1228Z OCT 01. 4711 BLKS.
2. BLK 1607, 0454Z SEP 27, T, MAX 0.5, MIN 0.5
P. 4.7, R 65, AZ123, V 314. 5 BLKS SIMILAR UNTIL 1900.
3. BLK 1855, 1310Z SEP 27, T, MAX 0.5, MIN 0.5
P. 5.1, R 64, AZ 357, V 300
4. BLK 2728, 1816Z SEP 28, T. MAX 0.6, MIN 0.7
P. 4.9, R 64, AZ 189, V 318
5. TAPE 81/36, 1238Z OCT 01 TO 0131Z OCT 02. 384 BLKS
6. BLK 175, 1832Z OCT 21, T, MAX 0.4, MIN 0.4
P. 5.2, RC 8 AZ 353, V 373, BLKS 292, 304 SIMILAR. AT BLK 384 TAPE WAS OVER HALF USED. I THEREFORE PULLED THE TAPE AND RESTARTED. TAPE OPERATION APPEARS NORMAL NOW.
REGARDS FULLERTON
MCMURDO STATION

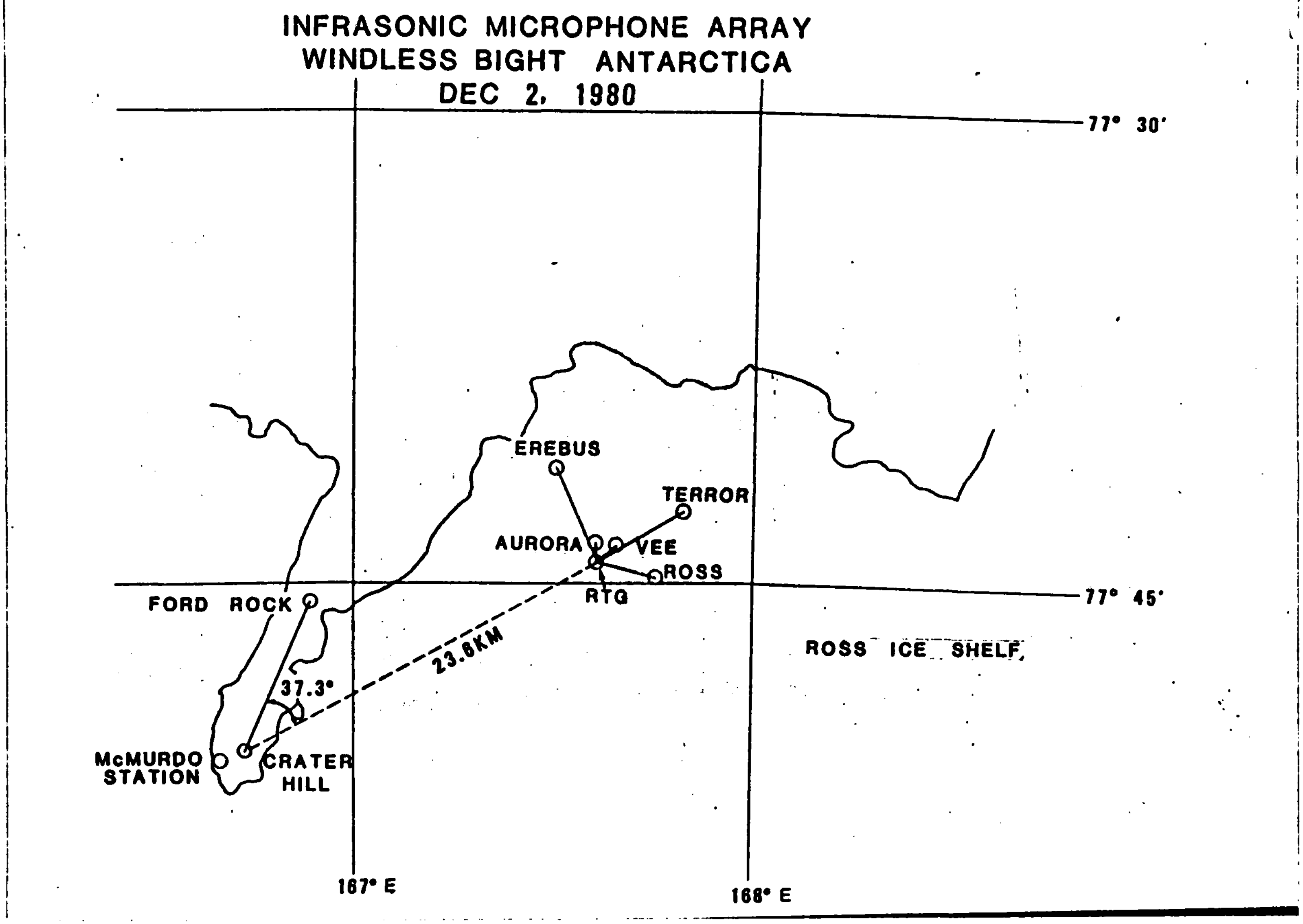

Figure 1. Windless Bight infrasonic microphone array.

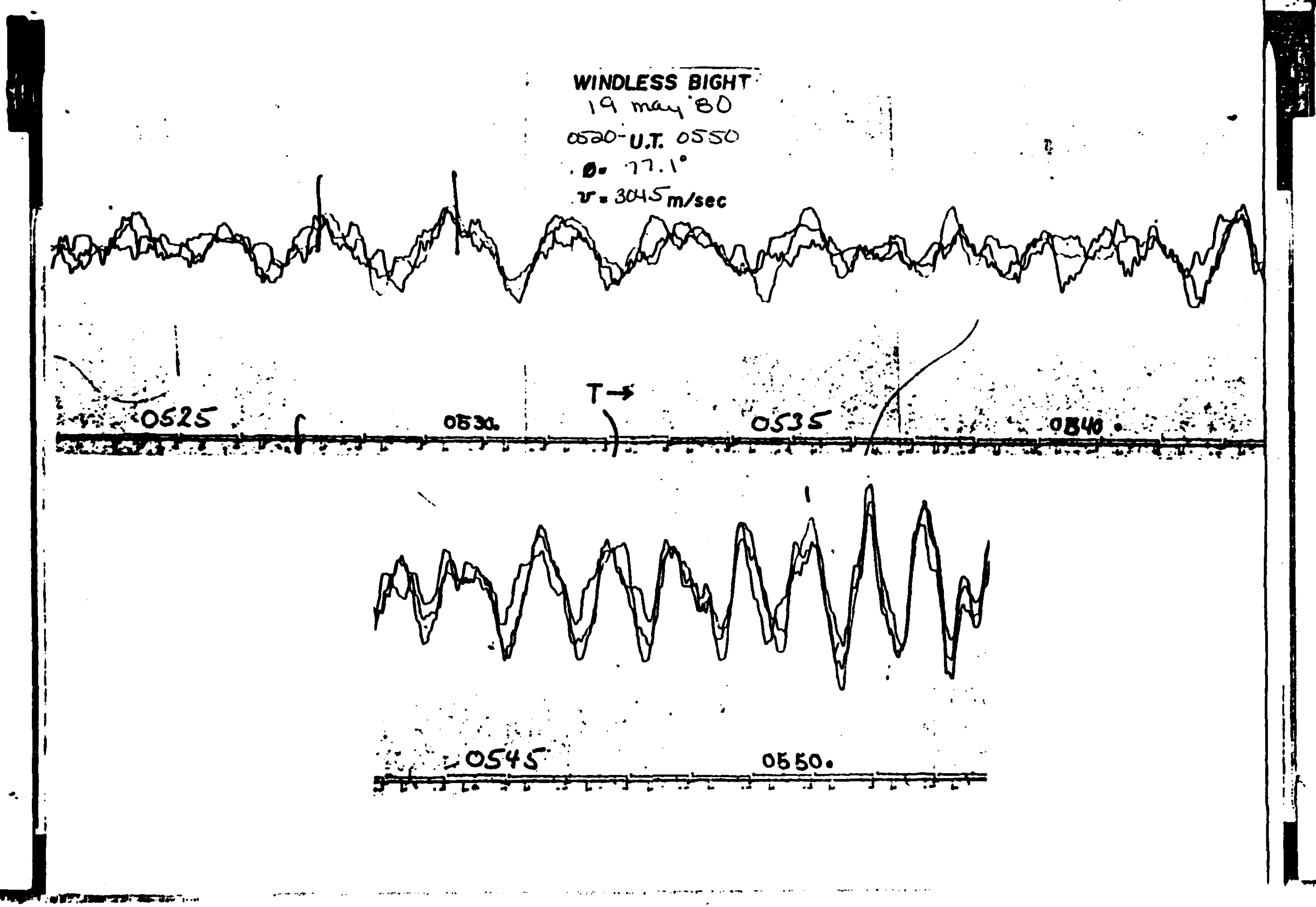

Figure 2. St. Helens great circle path infrasonic wave.

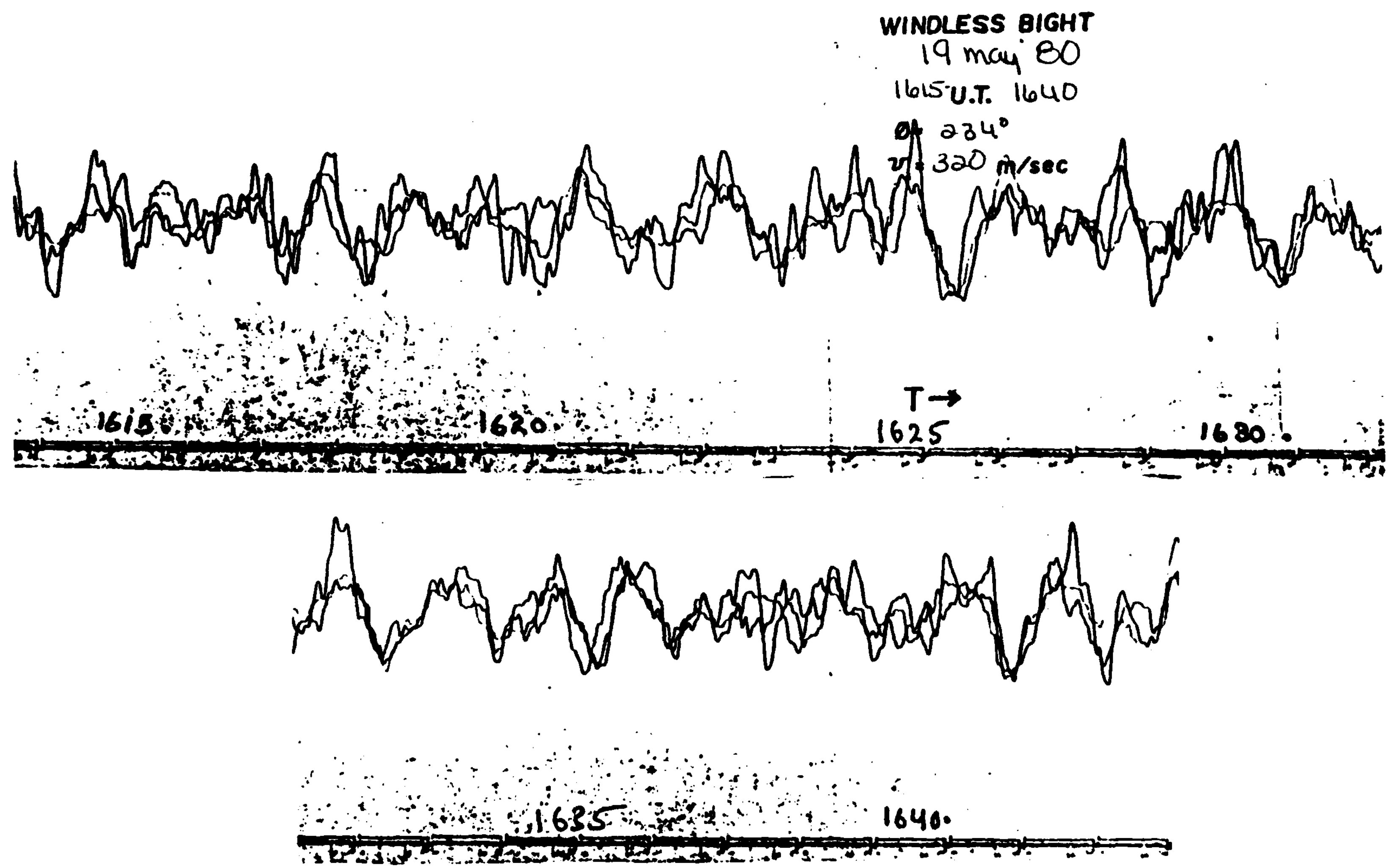

Figure 3. St. Helens antipodal path infrasonic wave

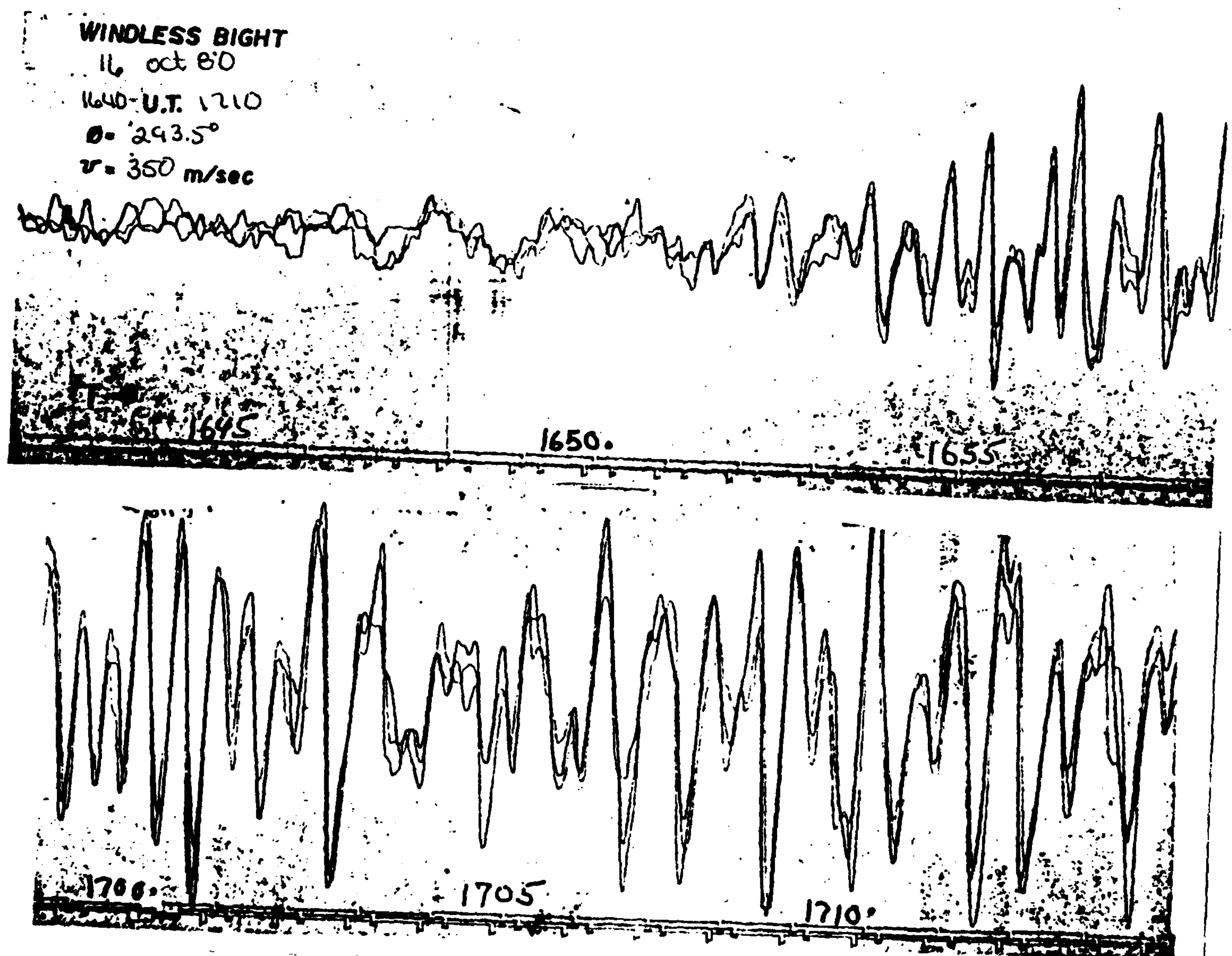

Figure 4. Chinese nuclear test infrasonic wave.

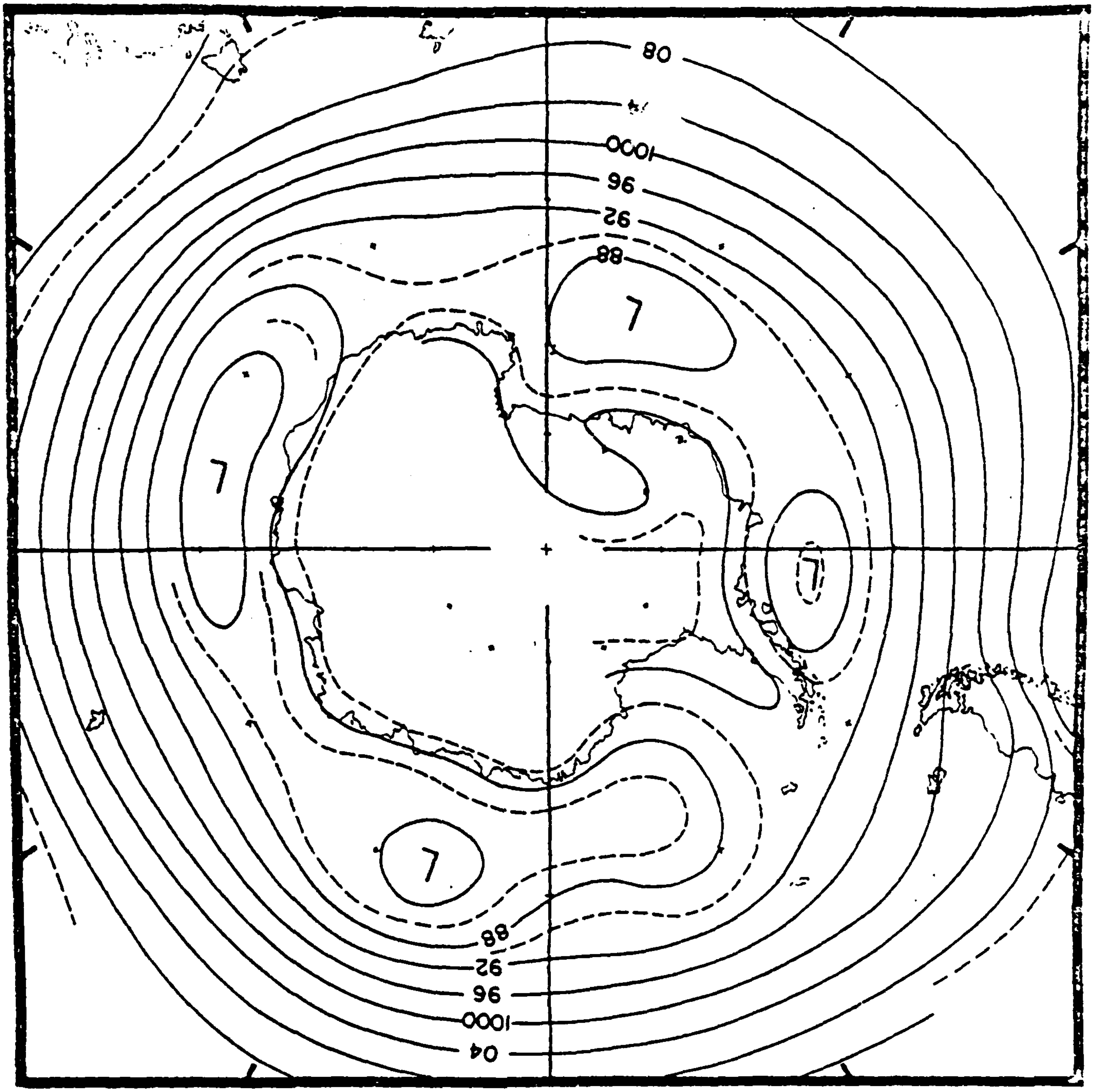

Figure 5. Barometric lows surrounding Antarctica.

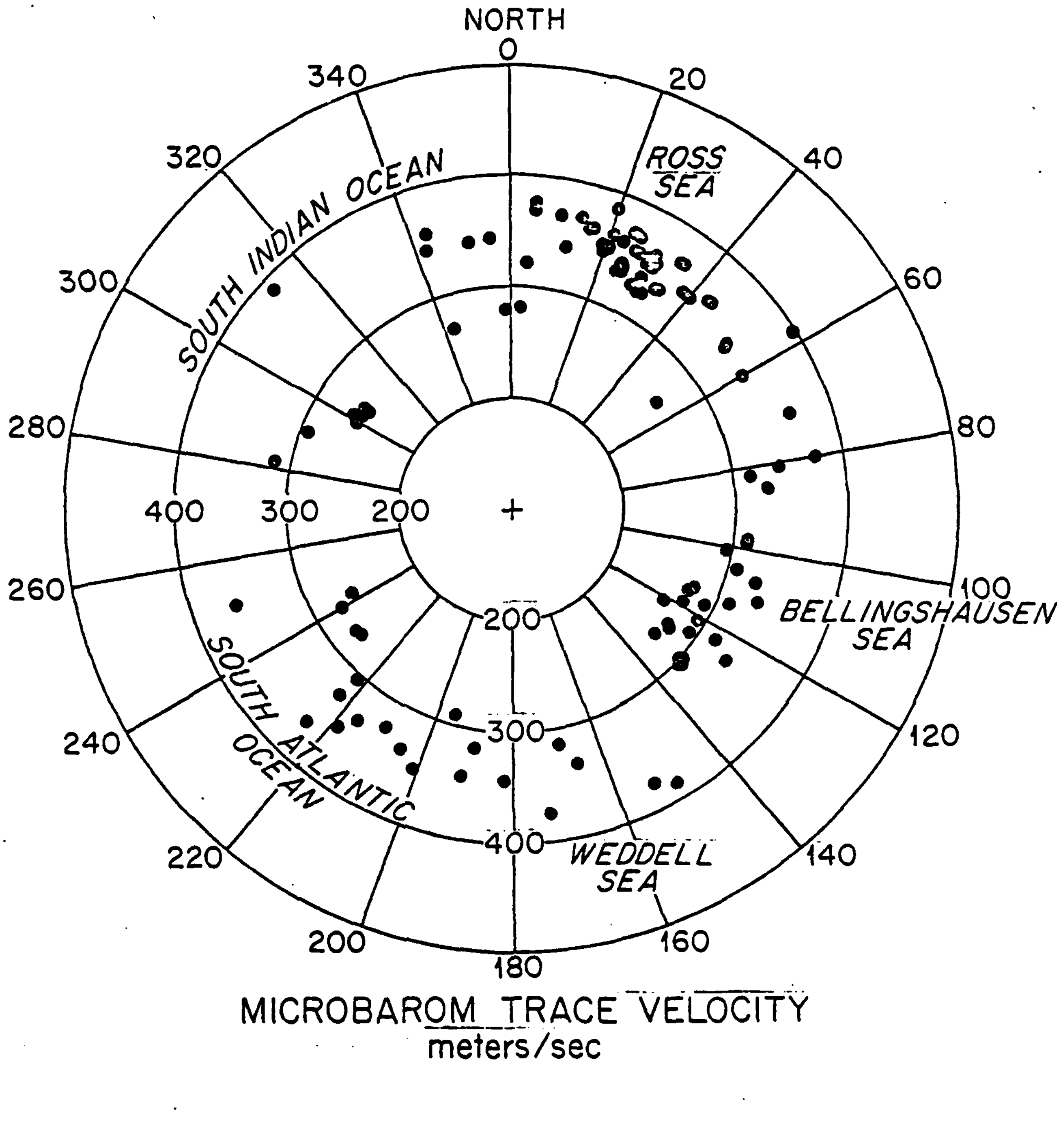

Figure 6. Microbarom trace velocity as a function of azimuth.

NOISE SUPPRESSION USING DATA-ADAPTIVE POLARIZATION FILTERS:
APPLICATIONS TO INFRASONIC ARRAY DATA

by

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November, 1981

ABSTRACT

We shall describe the constrution of a data-adaptive filter which is based upon the multivariate coherence of signals from an array of sensors. The measure of coherence used, called the degree of polarization, is constructed from invariants of the spectral matrix composed from the data and is rotationally invariant. Application of this filter to an infrasonic data suite is shown in which signal to noise level contrasts are enhanced by as much as 20db.

I. Introduction.

Noise suppression or rejection techniques are usually constructed based upon an assumed characteristic of the noise which is different from that of the signal. In processing multi-channel data from detector arrays it is commonly assumed that the noise field is isotropic and stationary as would be the case for noise associated with the individual detector electronics. Alternatively, the noise may be assumed to have a directional aspect as would be the case for waves generated by a distant source. Under such assumptions optimum techniques for signal to noise ratio enhancements may be defined. (See, Monzingo and Miller, 1980 and references therein).

In this paper we shall describe a technique for noise suppression which is dependent upon a measure of the multivariate coherence in a multi-channel signal. This measure is derived from the data themselves and may be used to define a filter which selectively removes the incoherent noise from the data. We shall take the point of view that the noise is simply less polarized, in a unitary space, than is the signal. This is a very general definition of signal versus noise and allows us to construct our filter. However, the filter is not optimally defined through this definition and one is led to the manipulation of several adjustable parameters. We have found that these parameters permit a wide range of choice with little effect on filter performance. In the final section of this paper we shall discuss the extension of the technique to an optimum filter design.

II. The Degree of Polarization, P.

A definition of the degree of polarization of a multivariate data sequence has been developed which is consistent with the concept of polarization as defined in optics and quantum mechanics (Samson, 1973; Olson and Samson, 1980). In this development the degree of polarization of a data sequence is investigated in the frequency domain where it is derived using the invariants of the spectral matrix. The formulation proceeds as follows. (A more detailed discussion in given in Samson and Olson, 1981).

Multi-channel time series may conveniently be represented by the vector

$$\underline{x}(t) = (x_1(t), x_2(t), \ldots, x_N(t))^T \tag{1}$$

where the $x_j(t)$ are the data derived from the jth sensor, $j = 1, N$, and T denotes the transpose. We begin constructing the spectral matrix, $\underline{S}(f)$, as follows:

$$\underline{S}(f, \delta) = \int_{f-\delta/2}^{f+\delta/2} \underline{Z}(g)\underline{Z}^+(g)dg \tag{2}$$

where

$$\underline{Z}(g) = \int_{-\infty}^{\infty} \underline{x}(t) \exp(-2\pi igt)dt \tag{3}$$

Here $\underline{Z}(g)$ is the Fourier transform of $\underline{x}(t)$ and $\underline{Z}^+(g)$ represents the Hermitean conjugate of $\underline{Z}(g)$. The spectral matrix is obtained from the outer product of $\underline{Z}(g)$ and $\underline{Z}^+(g)$ smoothed over some bandwidth, δ. Henceforth the dependence upon smoothing bandwidth will not be shown explicitly. It is well known that the spectral matrix is Hermitean and may be expanded in terms of its eigenvalues, λ_j, and its eigenvectors, $\underline{U}_j$, $j = 1, N$:

$$\underline{S}(f) = \sum_{j=1}^{N} \lambda_j \underline{U}_j(f)\underline{U}_j^+(f) \tag{4}$$

The vectors $\underline{U}_j(f)$ are, in general, complex and form a complete, orthonormal basis in a unitary space N dimensions. The eigenvalues j are real. We shall now consider the characteristics of a polarized signal in this unitary space.

If $\underline{S}(f)$ represents a pure-state (Fano, 1957) then it has only one non-zero eigenvalue and hence

$$\underline{S}(f) = \lambda_1 \underline{U}(f)\underline{U}_1^+(f) \tag{5}$$

To the extent that $\underline{S}(f)$ represents random, incoherent noise the eigenvectors become equal $\lambda_i = \lambda_j$, i, j = 1, N. Thus, when $\underline{S}(f)$ may be represented as a single outer product, as in (5), we shall call the signal state a pure-state and describe it as completely polarized. More detailed descriptions and discussions of these ideas are found in the papers by Samson (1973, 1977). Samson showed in the works cited that a measure of the degree of polarization, P, can be derived from the scalar invariants of $\underline{S}(f)$. It is given by

$$P(f) = \frac{N(Tr\underline{S}^2(f)) - (Tr\underline{S}(f))^2}{(N-1)(Tr\underline{S}(f))^2} \tag{6}$$

Here $Tr\underline{S}(f)$ is the trace of $\underline{S}(f)$. P(f) is a scalar which ranges $0 < P(f) < 1$. Since P(f) is constructed from scalar invariants of $\underline{S}(f)$ it is rotationally invariant. That is, it is not dependent upon the direction of arrival of the waves which traverse the array, as is, for example, the coherence.

III. Designing a Polarization Filter.

We may now proceed in a straight-forward manner to design a filter based upon the degree of polarization in the data. Given an N channel data segment, $\underline{x}(t)$, we first calculate its transform and from that the spectral matrix, $\underline{S}(f)$, and ultimately the degree of polarization, P(f), as described above. Then, the transform of the data is weighted by a suitable function of P(f) and the inverse transform is computed. In this way we have constructed a filtered data set whose spectral components are those for which $P(f)\sim 1$. It is composed of the pure-state components of the original data. The incoherent components have been suppressed wherever they occurred in the frequency domain.

If the filter length is equal to the length of the original data series, T_o, then the filtered data set is given by

$$\underline{Y}(t, \delta) = \frac{1}{2\pi T_o} \int_{-\infty}^{\infty} P^k(f, \delta)\, \underline{Z}(f) \exp(2\pi i f t)df \tag{7}$$

where

$$\underline{Z}(f) = \int_{-T_o/2}^{T_o/2} \underline{X}(t) \exp(-2\pi i f t)dt \tag{8}$$

Here, $P(f, \delta)$ is computed from the spectral matrix as defined in (2) and (6). The exponent k is a positive number which can be used to enhance the noise rejection of the filter. The details of constructing a sliding filter for discrete, multivariate data as well as examples of the application of the filter to data suites from various geophysical instrument arrays are given by Samson and Olson (1981).

IV. Application to Infrasonic Array Data.

During the period 1966 to 1981 an array of three infrasonic microphones was operated in Fairbanks, Alaska by the Geophysical Institute of the University of Alaska. Figure 1 shows the superposed, pressure versus time, analog records from a spaced array of four infrasonic microphones for a two hour segment of 28 February 1979. The data are divided into two panels and each shows a large amplitude pressure disturbance: the first just after 2130 UT and the second beginning just after 2201 UT. Elsewhere the record shows the presence of noise from boundary layer turbulence and microbarum pressure fluctuations. The pressure record from each station has been shifted slightly in time with respect to the other records to display the strong signal coherence. These signals resulted from the an earthquake of magnitude 7.3 that occurred at 2127 UT on 28 February, 1979 near Yakataga, Alaska. The first pressure disturbance near 2130 UT was produced by infrasound generated by the vertical component of the local ground motion as the surface seismic waves passed through the array. The longer pressure wave burst occurring after 2200 UT is due to the infrasonic waves that were produced by vertical ground motion near the earthquake epicenter. The infrasonic wave at 2200 UT propagated in the stratospheric soundchannel from Yakataga 563 km to the Fairbanks array. The pressure disturbance at 2130 associated with local ground motion has a horizontal trace velocity that is characteristic of surface seismic wave velocity of about 1,700 m/sec. The pressure wave that arrived at 2200 U.T. has a horizontal trace velocity of 322 m/sec and thus can be identified as an air wave that propagated to Fairbanks from Yakataga in the stratospheric sound channel. (See Wilson and Forbes, 1969).

The data from the original data records shown in Figure 1 were hand digitized to provide a sample every 1.8 seconds and low pass filtered to remove the high frequency contamination introduced by the digitization process. The resulting data for the half hour interval containing the infrasonic wave arrivals are shown in Figure 2. In Figure 3 we show the same data after treatment with the polarization filter. In this case the filtering was done using a sliding window 9 minutes long. That is, data from sequential 9 minute segments of the original 3 channel input stream were purefiltered and concatenated after trimming the filter transients as described in Samson and Olson (1981). The most obvious feature of the filtered data is the clarity of the onset of the arrival of the infrasonic waves at the array. As well, one may discern a frequency dispersion through the event with the low frequencies arriving first.

The spectra of the signal from the microphone at Ballaine Lake before and after filtering are shown in Figures 4 and 5. While the overall power levels have been reduced by the effect of the filter, there is considerable enhancement of the contrast between the central peaks and the noise, particularly at low and high frequencies. For example, the noise level at 10^{-3} Hz has been reduced by approximately 3 orders of magnitude while the low frequency signal peak near 10^{-2} Hz has suffered a reduction of less than a factor of 10. This results in an overall enhancement of the signal to noise power for these two frequencies of approximately two orders of magnitude, or 20 db. The polarization filter technique is particularly useful in treating infrasonic microphone data because the principal source of noise, boundary layer wind turbulence, produces pressure fluctuations that are uncorrelated over the scale size of the microphone array. In Figures 6 and 7 we show sonograms of the signal from the Ballaine Lake sensor. Here power levels are contoured at 3 db levels from the peak power with cross hatching showing values within 6 db of the peak. In both sonograms the signal dispersion noted in the discussion of the original time series is evident with low frequency power arriving first. However, the separation of the signal power into two principal frequency bands is much clearer in the filtered sonogram.

While the filtered signals shown in Figure 2 were derived from a sliding polarization filter, it is instructive to observe the shape of the polarization filter derived from the entire 30 minute, 3 channel data suite. Figure 8 shows the estimates of the degree of polarization as a function of frequency as computed from the entire data suite. Although one expects P(f) to approach zero for infinite random data sequences, finite values of P(f) occur when one treats finite length data suites. Olson and Samson (1980) have shown that for random noise at 12 degrees of freedom one expects $P(f) < 0.6$ at a 95% confidence level. We can see in Figure 8 that significant values of P(f), and thus pure signal states, occur at a number of locations in the spectrum; principally near 0.05 and 0.12 Hz. Again, the net result is shown in the spectrum of Figure 5. Figure 8 reinforces the idea that the filter is adapted to the data and incoherent signals are suppressed wherever they may occur in the spectrum.

Traditional analyses of infrasonic signals have relied upon least-square estimators to provide velocity and azimuth information. These algorithms rely on ones ability able to estimate the delay times between the arrival of the signal at the various sensors, or equivalently upon the estimates of phase differences between spectral components at dominant signal frequency. In the time domain estimates of signal delays may be obtained by computing the cross correlation between a pair of signals and searching that function for a maximum. The filtering process has a strong effect on the cross correlation function. First, it enhances the magnitude of the peak value and second, it produces some oscillations in the wings of the autocorrelation function since the noise has been removed from the data and it now appears more harmonic in content. These effects are evident in the cross correlation function derived from the data from the Ballaine Lake and Gold Hill microphones as shown in Figure 9. It has been our experience that the enhancement of the primary maximum in the cross correlation function has added reliability to the determination of signal delays for cases of marginal signal to noise level.

In both frequency and time domain analyses of signals from filtered data one must be careful to avoid biases in the estimated parameters introduced by phase distortions which result when sliding data windows are used. In the case where large data sequences are processed piece-wise and patched together signal distortion can occur at the edges of the data windows. This is true for any filtering process, and particularly for data adaptive filters such as the one we are describing. One must exercise some care in selecting the window sequence so as to minimize or eliminate these distortions. The problem arises when one applies an analysis routine over a data segment which is different in length from the segment used in the filtering procedure. Often the problem may be avoided by proceeding directly to subsequent analysis after filtering a segment of data.

V. Extensions.

The filter design as we have described it is based upon the assumption that signals can be differentiated from noise in a multi-channel data suite by virtue of a measure of the multivariate coherence. In the case where the noise is truly incoherent the filter works remarkably well. However, when the noise has coherence or is polarized in some sense it will not be rejected by this technique. Such noise fields arise in infrasonic studies, for example, when one sensor is subjected to excessive wind noise producing what seems to be linearly polarized signals within our framework. Another source of contamination is the arrival of signals from "uninteresting" sources in other frequency bands or from other directions. The resolution of these problems can be approached through the modification of the spectral matrix which represents the data in such a way as to reduce the noise components.

Consider the detection of a signal in the frequency domain as the projection of the information contained in the spectral matrix upon a subspace represented by the signal. The projection can be written as a quadratic form

$$D = \underline{a}\ \underline{S}\ \underline{a}^{+} \tag{10}$$

where $\underline{S}$ is the spectral matrix, $\underline{a}$ is the vector which represents the signal is a unitary space and D represents the scalar power in the $\underline{a}$ direction. In equation (10) $\underline{S}$ can be thought of as a metric which defines the signal space being investigated. If we want to assure minimum response to a noise field represented by the matrix $\underline{Q}$ then we would like to change the metric so as to project our signal power onto a subspace orthogonal to the principal eigenvectors of $\underline{Q}$. This can be done by through the transformation of $\underline{S}$ to $\underline{S}'$ given by

$$\underline{S}' = \sqrt{\underline{Q}}^{+}\ \underline{S}\ \sqrt{\underline{Q}} \tag{11}$$

Then, having conditioned our signal spectrum by the noise spectrum which is present we may apply the polarization filter to $\underline{S}'$ with the prospect of signal to noise enhancement. Clearly, the efficacy of this procedure depends upon the extent to which $\underline{Q}$ represents the noise in the data. Hopefully, the noise is stationary enough that $\underline{Q}$ can be estimated from a patch of data which occurs just prior to the arrival of the signal. We are investigating this approach to pure-state filtering at present.

VI. Conclusions.

We have described the construction of a data-adaptive filter which is based upon the multivariate coherence of the signals in a data suite and showed its application to infrasonic data. Under most circumstances it serves as an effective method for enhancement of the signal to noise ratio of the data, often by as much as 20 db. This enhancement increases the observers ability to detect arrivals of various wave packets across his array as well as his ability to discriminate features of multiband signals. We are currently studying its extension to non-random noise fields through the modification of the spectral matrix described above.

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Figure Captions

Figure 1. Superposed analog records from a spaced array of four infrasonic microphones located in Fairbanks, Alaska. The data show microphone responses to signals from the Yakataga, Alaska earthquake of 28 February, 1979. The records have been shifted in time to display the strong signal correlation. See the text for details.

Figure 2. Digitized data sequences taken from the records shown in Figure 1 and covering the interval 2150 UT to 2220 UT on 28 February, 1979. These data are from the Gold Hill (GH), Airport (AP) and Ballaine Lake (BA) sites in the Fairbanks, Alaska region.

Figure 3. The data shown are those which result from the of the pure-state polarization filter to the data shown in Figure 2. Note the reduction in noise prior to $t = 8$ minutes. The data after $t = 22$ minutes have been set to zero arbitrarily.

Figure 4. The power spectrum of the raw, digitized data from the Ballaine Lake microphone as shown in Figure 2. The spectrum has been smoothed to yield estimates with approximately 12 degrees of freedom. The 95% confidence limits are shown by the small bar on the plot.

Figure 5. The power spectrum of the Ballaine Lake signal after pure-state filtering. Again, the spectrum is characterized by 12 degrees of freedom. Note the suppression of the noise, especially near 10^{-3} Hz compared with that shown in Figure 4.

Figure 6. A sonogram of the raw Ballaine Lake signal showing the temporal evolution of signal power. The power levels have been contoured in 3db steps. The small cross shows the frequency and time domain window sizes.

Figure 7. A sonogram of the pure-state filtered Ballaine Lake data showing the temporal evolution of the signals. The separation of low and high frequency signal components is clearer than that shown in Figure 6.

Figure 8. The pure-state polarization filter amplitude function which results when data from the three microphones shown in Figure 1 are used. See the text for details.

Figure 9. This figure shows the changes in the cross correlation between the Ballaine Lake and Airport signals which occur when the data are filtered. The peak value of the cross correlation is increased substantially after filtering. The oscillations in the skirts result from the filtering process having removed non-harmonic components.

References

Fano, U., Description of states in quantum mechanics by density matrix and operator techniques, Rev. Mod. Phys., 29, 74, 1957.

Monzingo, R.A. and T.W. Miller, Introduction to Adaptive Arrays, John Wiley & Sons, New York, 1980.

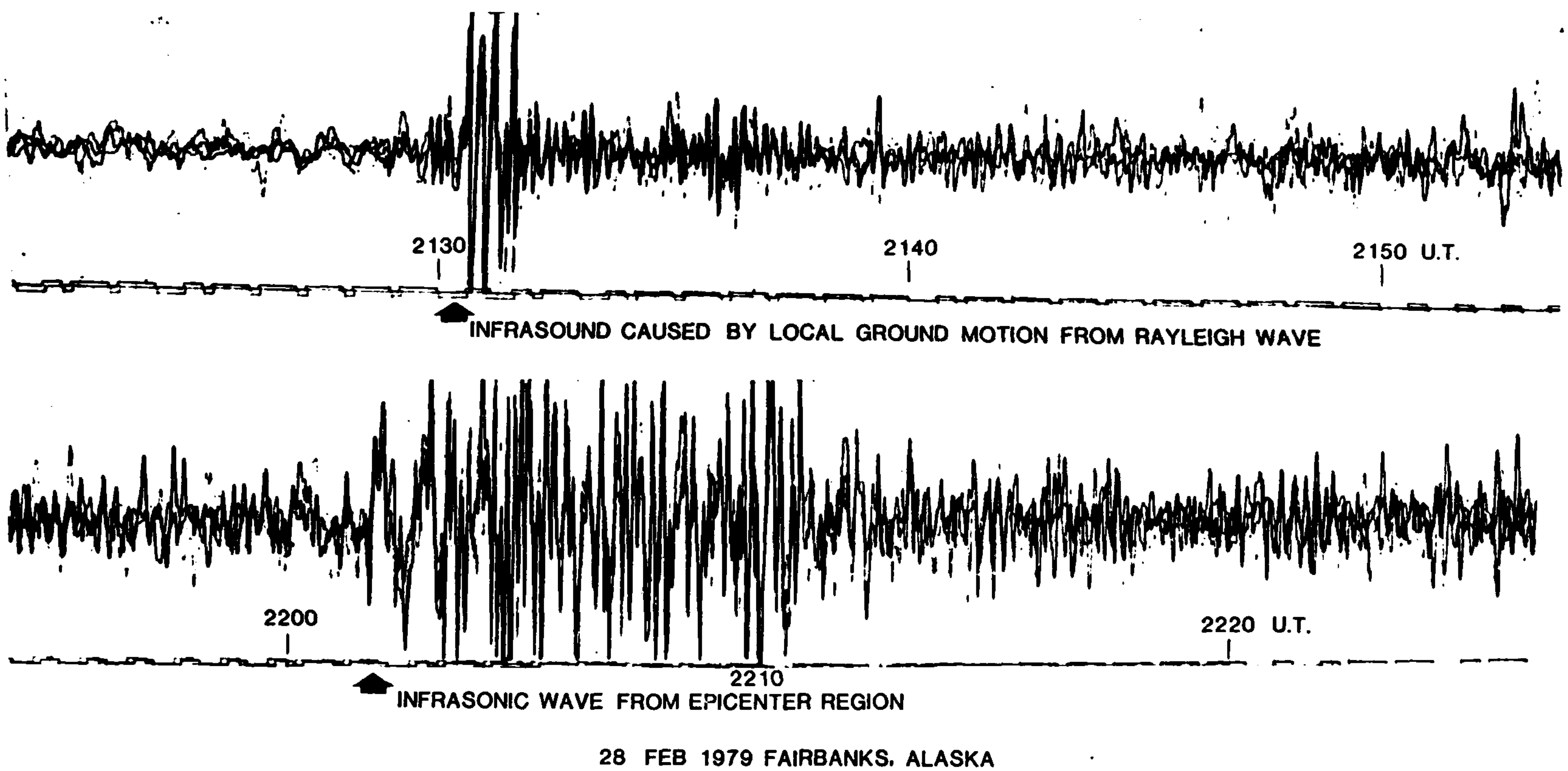
Olson, J.V. and J.C. Samson, Generalized power spectra and the Stokes vector representations of ultralow frequency micropulsation states, Can J. Phys., 58, 123, 1980.

Samson, J.C., Descriptions of the polarization states of vector processes: Applications to ULF magnetic fields, Geophys. J. R. Astr. Soc., 34, 403, 1973.

Samson, J.C., Matrix and Stokes vector representations of detectors for polarized waveforms: theory with some applications to teleseismic waves, Geophys. J. R. Astr. Soc., 51, 583, 1977.

Samson, J.C. and J.V. Olson, Data adaptive polarization filters for multichannel geophysical data, Geophysics, 46, 1423, 1981.

Wilson, C.R. and R.B. Forbes, Infrasonic waves from Alaskan volcanic eruptions, J. Geophys. Res., 74, 4511, 1969.



2130
2140
2150 U.T.
INFRASOUND CAUSED BY LOCAL GROUND MOTION FROM RAYLEIGH WAVE
2200
2210
2220 U.T.
INFRASONIC WAVE FROM EPICENTER REGION
28 FEB 1979 FAIRBANKS, ALASKA

Fig. 1

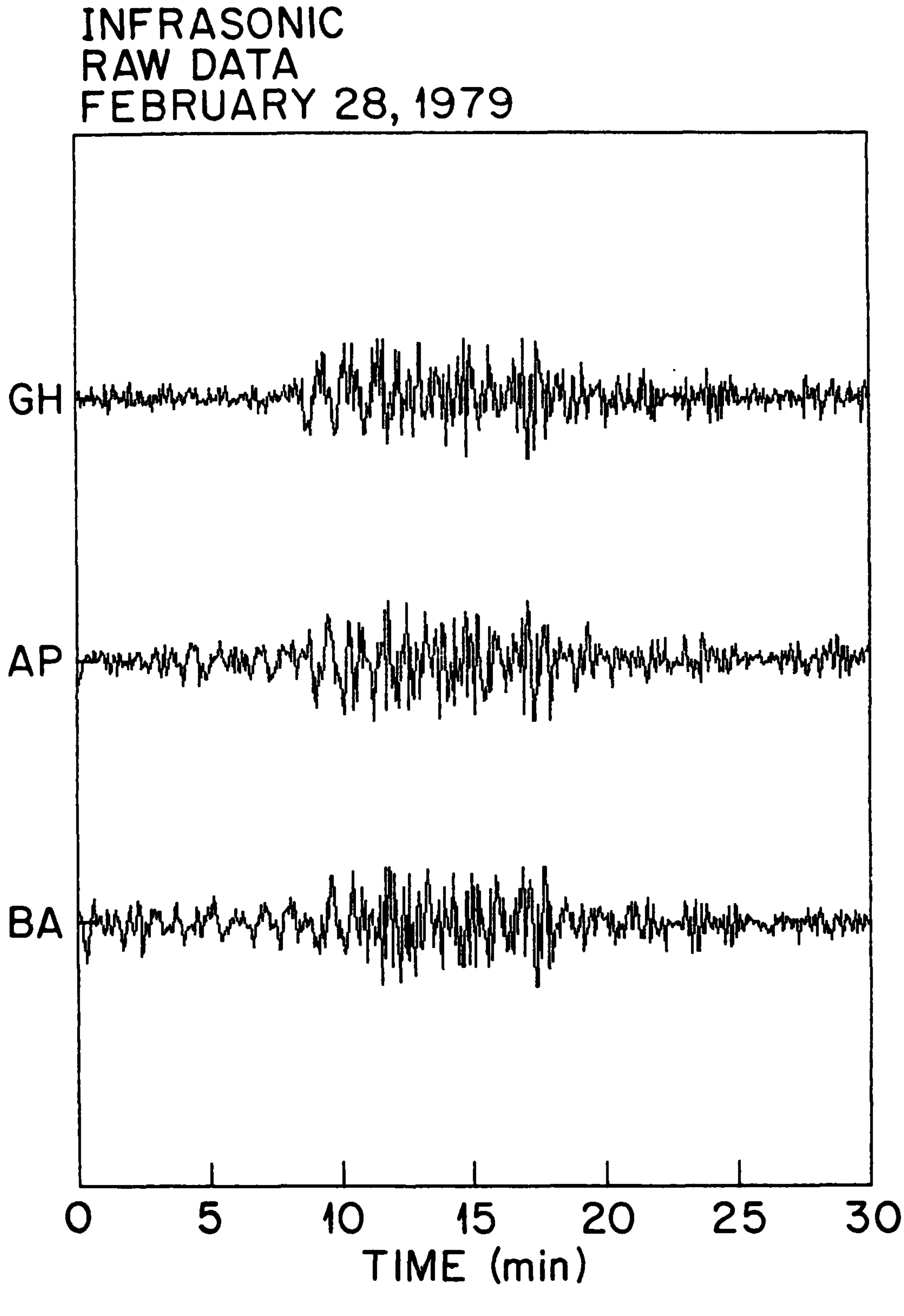

INFRASONIC
RAW DATA
FEBRUARY 28, 1979
GH
AP
BA
0
5
10
15
20
25
30
TIME (min)

Fig. 2

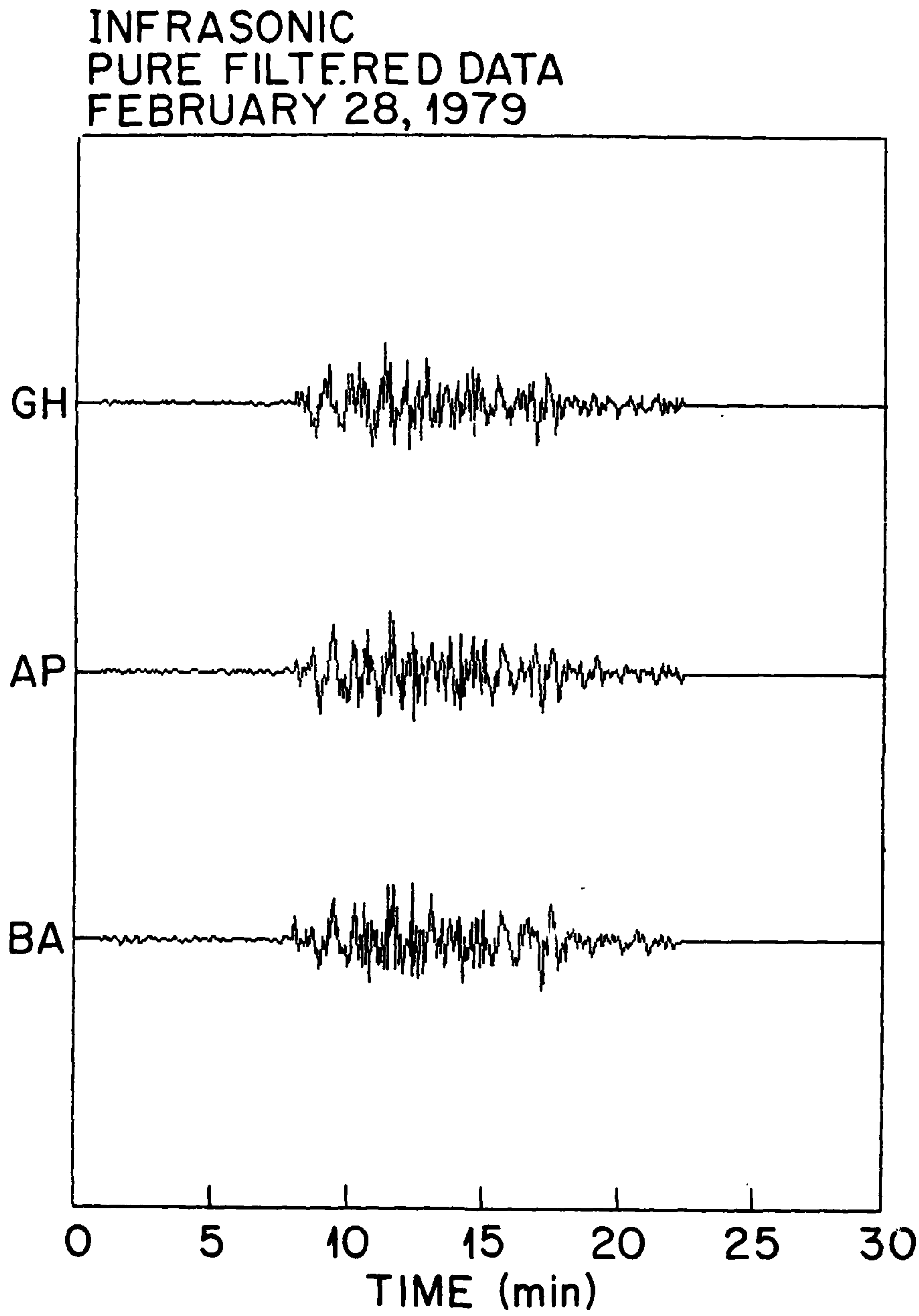

INFRASONIC
PURE FILTERED DATA
FEBRUARY 28, 1979
GH
AP
BA
0
5
10
15
20
25
30
TIME (min)

Fig. 3

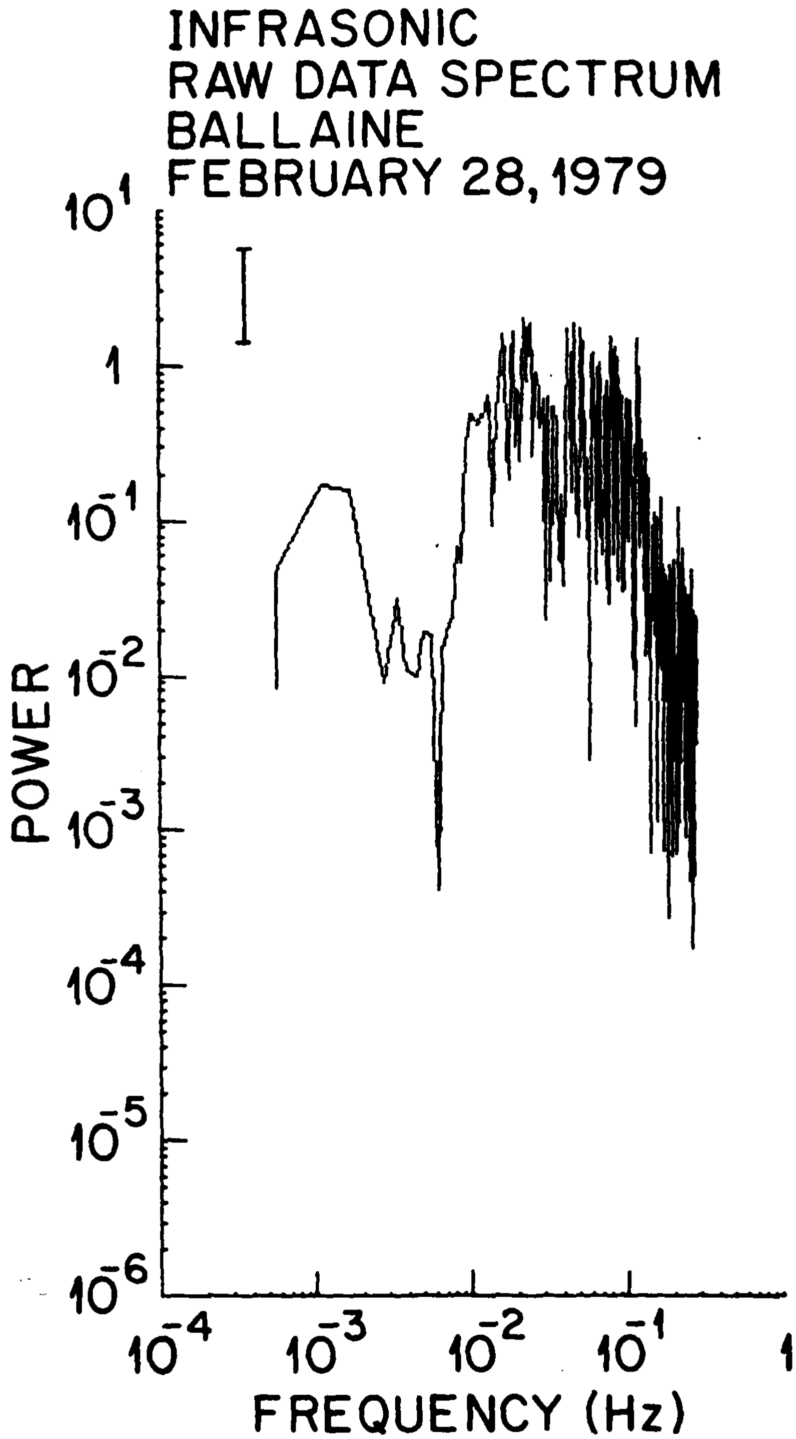

INFRASONIC
RAW DATA SPECTRUM
BALLAINE
FEBRUARY 28, 1979
POWER
10^1
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
FREQUENCY (Hz)

Fig. 4

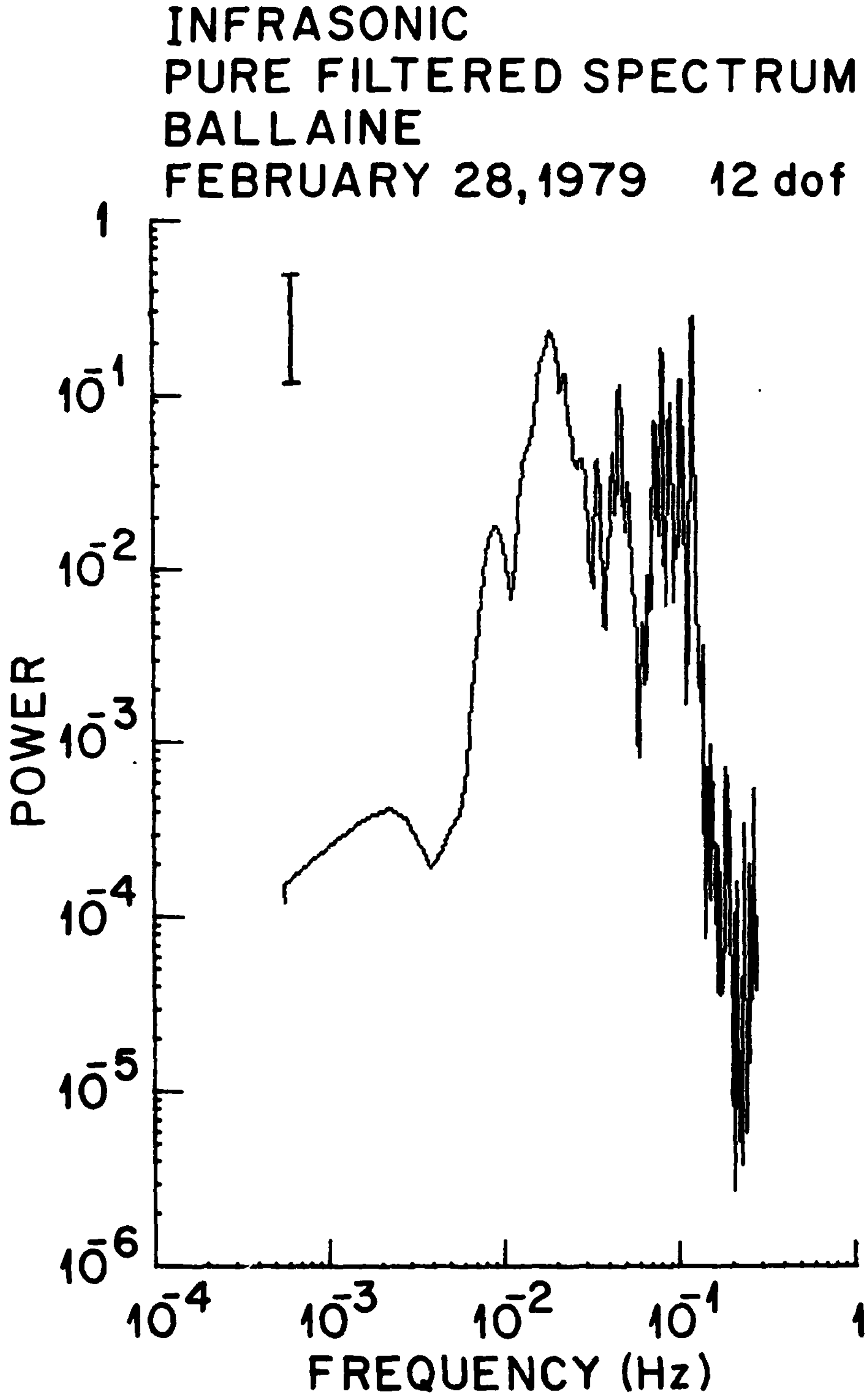
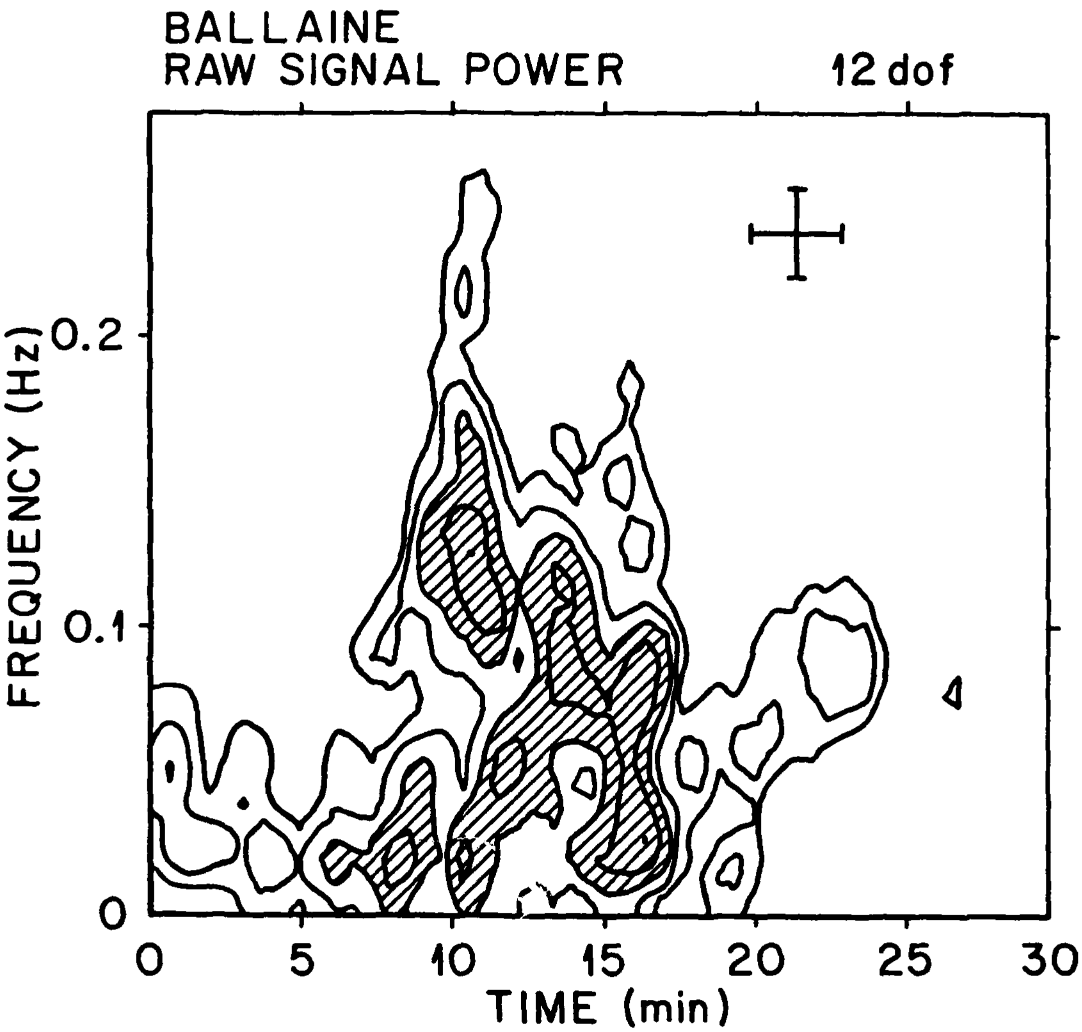
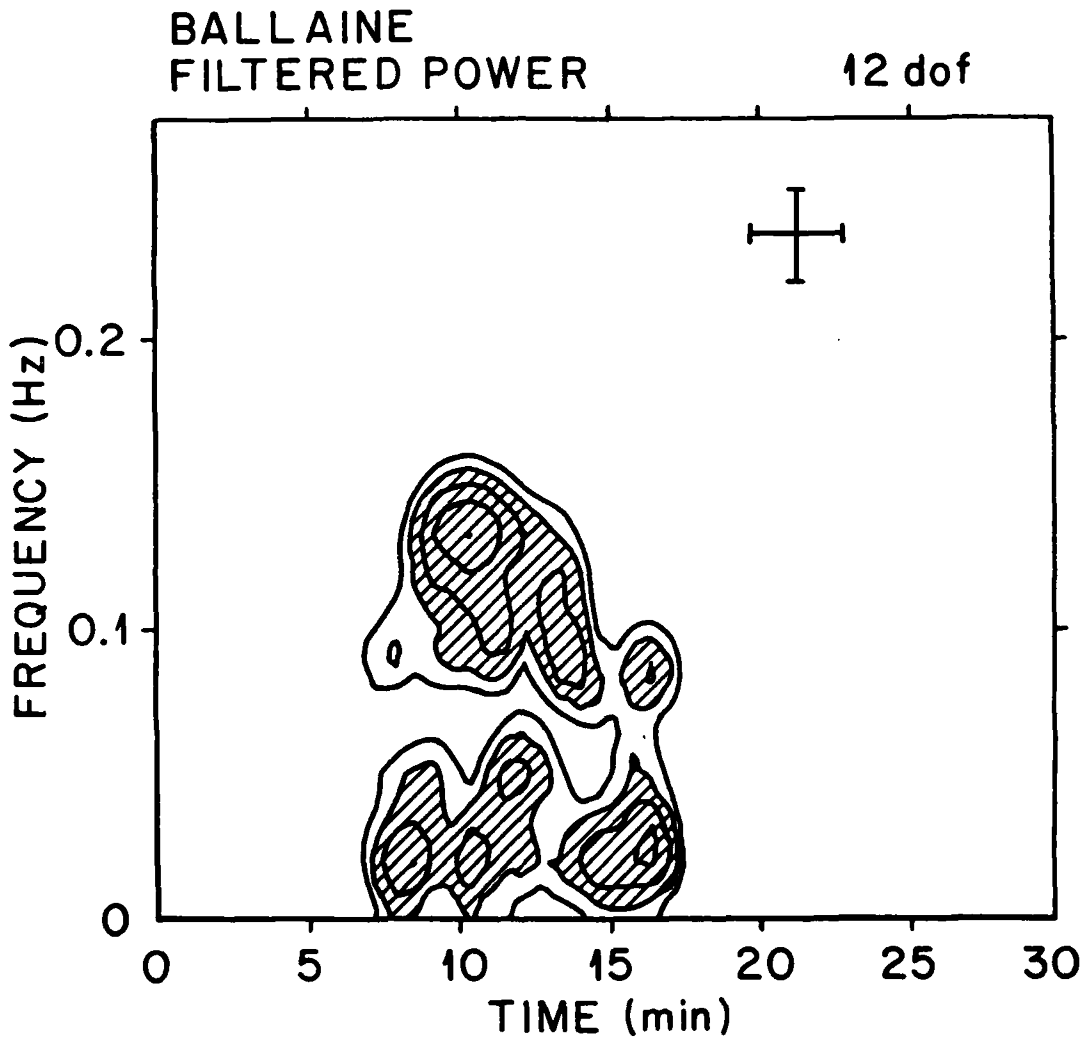

INFRASONIC
PURE FILTERED SPECTRUM
BALLAINE
FEBRUARY 28, 1979 12 dof
POWER
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
FREQUENCY (Hz)

Fig. 5



BALLAINE
RAW SIGNAL POWER
12 dof
FREQUENCY (Hz)
0.2
0.1
0
0
5
10
15
20
25
30
TIME (min)

Fig. 6



BALLAINE
FILTERED POWER
12 dof
FREQUENCY (Hz)
0.2
0.1
0
0
5
10
15
20
25
30
TIME (min)

Fig. 7

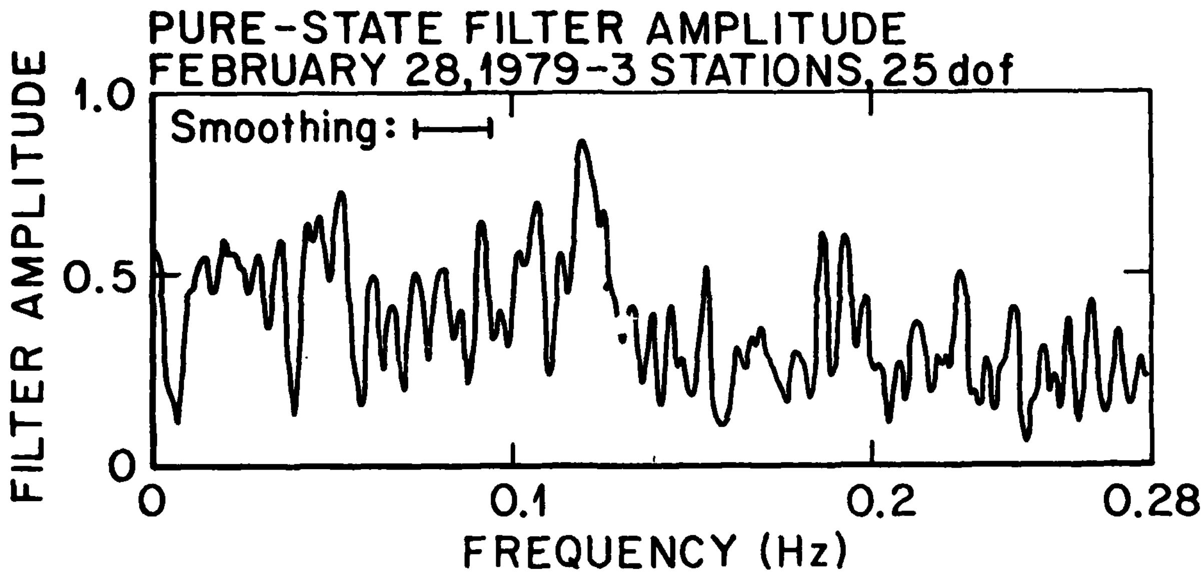

PURE-STATE FILTER AMPLITUDE
FEBRUARY 28,1979-3 STATIONS, 25 dof
Smoothing:
FILTER AMPLITUDE
1.0
0.5
0
0
0.1
0.2
0.28
FREQUENCY (Hz)

Fig. 8

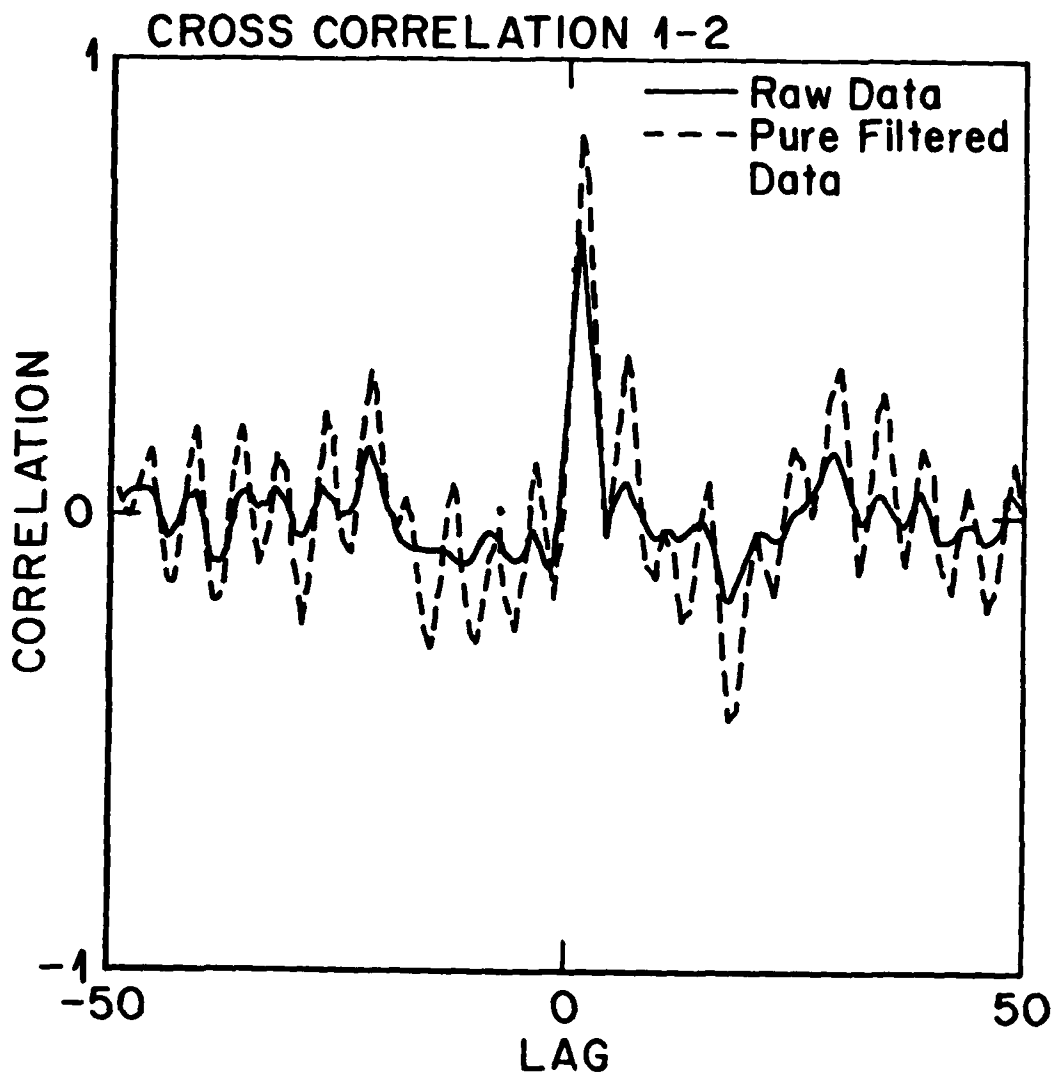

CROSS CORRELATION 1-2
Raw Data
Pure Filtered Data
CORRELATION
1
0
-1
-50
0
50
LAG

Fig. 9

Unclassified

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A summary is given of the project chronology and the reports describing our research in Antarctic Atmospheric infrasound. Analysis of selected infrasonic signals is discussed and a list is given of all infrasonic waves received on the digital system with correlation coefficient greater than 0.6.

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